CONSEIL PERMANENT INTERNATIONAL POUR
L'EXPLORATION DE LA MER
34 B. STRANDVEJ, HELLERUP — DANEMARK

RAPPORTS
ET
PROCÈS-VERBAUX DES RÉUNIONS

VOLUME LXXXVIII

SCIENTIFIC REPORT OF THE NORTH-EASTERN AREA COMMITTEE

1934

PUBLISHED BY

OSCAR SUND

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

Prix: Kr. 4.00.

Juin 1934.

COPENHAGUE — IMPRIMERIE BIANCO LUNO A/S

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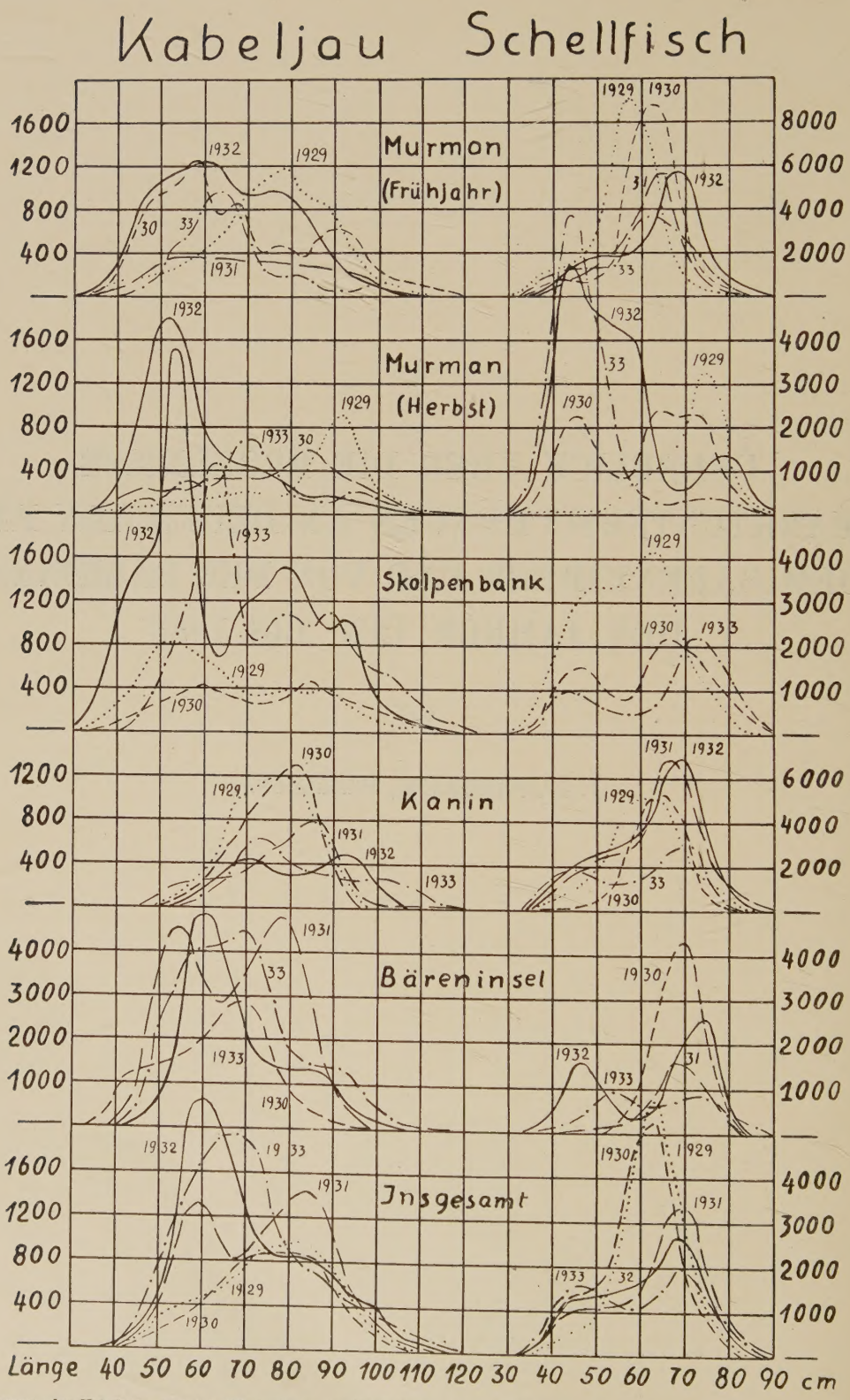
I

ÜBERBLICK ÜBER DIE ERGEBNISSE DER MARKTUNTERSUCHUNGEN AN DEUTSCHEN FÄNGEN AUS DEM BARENTSMEER UND VON DER BÄRENINSEL IN DEN JAHREN 1929 BIS 1933

VON

J. LUNDBECK, Wesermünde



Lingenkurven der Kabeljau- und Schellfischerträge im Barentsmeer (einschl. Bäreninsel), berechnet in 5-cm.-Gruppen als mittlerer Fang je Fangreise der deutschen Fischdampfer. (Die Kurven für das Gesamtgebiet sind berechnet auf Grund der Fangstatistik für eine Fangperiode vom 1. Juni bis 31. Mai des folgenden Jahres; die Kurven für 1933/34 sind vorläufig).

ie nunmehr vorliegenden Untersuchungen aus fünf aufeinander folgenden Jahren zeigen einen merkenswerten Wechsel in den Fischereibedingun-, den kurz darzustellen der Zweck der nach-genden Ausführungen ist. Sehr entschieden kündigt beim Kabeljau, in weitgehender Übereinstim-ng mit den Ergebnissen der norwegischen Fischerei-ersuchungen, der Beginn einer neuen Fangperiode in der Weise, dass die anfangs vorherrschenden ssen und alten Fische stark abgenommen haben, dass jüngere Jahrgänge nunmehr die Grundlage Fischerei bilden. Ein ganz ähnlicher Vorgang t sich auch beim Schellfisch, wenn auch die etwas ersartige Lebensweise, im besonderen die Vorliebe kleinen Schellfisches für tiefes Wasser (ausserhalb Bereichs der Fischerei) die Ablösung der älteren he durch den jungen Nachwuchs verzögert und heute noch bei weitem nicht so klar hat in Er-einung treten lassen. Dies wird in Zukunft wohl n mehr der Fall sein. Es ist aber wichtig fest-ellen, dass in diesem Falle die fluktuierenden Ver-erungen im Bestande der beiden Fischarten ein-er sehr ähnlich sind.

Wichtig ist ferner, besonders auch für die Fischerei, an verschiedenen Plätzen die Alters- und Längen-mmensetzung der marktfähigen Bestände beider zfische sehr ungleichartig ist. Der genannte Wech-n der Menge der einzelnen Alters- und Längen-pen wirkt sich daher örtlich in sehr verschiedenem se und in ungleicher Weise aus. Zum Verständnis Lage ist es deshalb notwendig, die einzelnen, für Fischerei wichtigsten Teile des Gebietes gesondert einander zu betrachten. Dazu ist von Anfang an Einteilung in die Gebiete "Murman" = dem enstreifen bis 40° O., "Skolpen" = dem Gebiet lich der Südrinne, "Kanin" = dem Gebiet östlich 40° O. mit geringeren Tiefen als die vorher-nnten, und seit 1930 "Bäreninsel" = Spitzbergen-vorgenommen worden.

im Kabeljau zeigte sich von Anfang an, dass n allgemeinen mehr zerstreut ist als der Schell-. Eine durch die Längenzusammensetzung gut akterisierte Gruppe, die grössten noch unreifen he, mit Längen um 80 cm., hält sich im Winter Kanin-Gebiet auf. Weiter westlich finden sich vorwiegend die grösseren Laichfische mit Längen > 80 cm., und auch die kleinsten marktfähigen Fische mit Längen von 50—60 cm. Diese letzteren werden im Gegensatz zu der norwegischen Fischerei von der deutschen vor allem im Herbst gefangen, wenn sie durch ihre Abwanderung nach der Tiefe in das Tätigkeitsfeld der deutschen Fischdampfer geraten. Im Frühjahr sammelt sich mehr oder weniger der ganze Bestand des südlichen bis östlichen Barentsmeeres, soweit er nicht zum Laichen gezogen ist, an der westlichen Murmanküste. Das Bäreninsel-Gebiet nimmt eine Mittelstellung ein in so fern, als neben grösseren Fischen von 70—80 cm. Länge auch in verschieden grosser, zeitweise überwiegender Menge kleinere Tiere in den Fängen von dort enthalten sind. Möglicherweise findet hier eine ähnliche Sonderung nach Grössengruppen wie im inneren Barentsmeer, nur auf kleinerem Raum und mit stärkerer Ortsveränderung statt. Jedenfalls stehen die Kabeljaubestände beider Gebiete anscheinend nicht regelmässig in Beziehung zu einander, vielmehr scheint sich der Kabeljaubestand der Spitzbergenbank aus dem Meeresgebiet nördlich von Norwegen zu rekrutieren, und ein Austausch mit dem inneren Barentsmeer, der in einigen Fällen wahrscheinlich ist, erfolgt wohl nur auf dem Umwege über Norwegen.

Der Rückgang des Anteils der grossen Fische musste sich in der Hauptsache im Kanin-Gebiet geltend machen, weil hier die kleineren Tiere am wenigsten zahlreich sind. Tatsächlich trat dort von 1930 auf 1931, nachdem vorher der Bestand im wesentlichen unverändert seit 1929 der gleiche geblieben war, ein erheblicher Rückgang ein, der 1932 noch deutlicher wurde. Eine Zunahme der Fische ähnlicher Grösse 1931 bei der Bäreninsel und 1932 auf Skolpenbank wird, obgleich nicht unmittelbar erwiesen, damit in Zusammenhang gebracht und in der Weise erklärt, dass die heranreifenden Kabeljau sich 1931 in das westliche Barentsmeer gewandt und dort eine Zeit lang die Weidegründe der Spitzbergenbank aufgesucht hatten, nach der Rückkehr vom Laichen dann, wie es wahrscheinlich die Regel ist, nur bis an die äussersten Ausläufer des Flachwassergebietes des inneren Barentsmeeres vordrangen.

Die heranwachsenden jungen Tiere machten sich,

nachdem sie schon in den Jahren vorher, ohne marktfähig zu sein, von den Netzen der Fischdampfer in auffälliger Menge erbeutet worden waren, zuerst 1931 bei der Bäreninsel, ein Jahr später auch an der Murmanküste und auf Skolpenbank stark bemerkbar. Dieser zeitliche Unterschied im ersten Auftreten erklärt sich wohl aus Wachstumsverschiedenheiten, denn noch 1932 waren die jungen Kabeljau in den Fängen von Skolpenbank im Mittel etwa 8 cm. kleiner als in denen von der Bäreninsel. 1933 zeigt die Kurve der Längenzusammensetzung der Kabeljau von der Bäreninsel Neigung zur Zweigipfligkeit; es ist möglich, den kleineren Gipfel bei 60 cm. durch eine Zuwanderung langsamer gewachsener Kabeljau, etwa aus dem südwestlichen Teil des Barentsmeeres, zu erklären. Im Kanin-Gebiet machen sich die neuen Jahrgänge 1932 erst schwach, 1933 etwas stärker bemerkbar, und zwar sind nur die grössten Angehörigen dieser neuen Welle in dieses Gebiet gewandert; 1932 befand sich der Mengengipfel bereits bei 70 cm. Länge, d. h. um 10 cm. gegen den in den Bäreninsel-Fängen verschoben. Erst 1933 bildeten sie die Grundlage des Kabeljaufanges in dieser Gegend, besonders in geringeren Wassertiefen, wo die grösseren Tiere ($>$ 80 cm.) an Zahl nur noch unbedeutend beteiligt waren. Gerade hier ist aber noch mit einem Steigen des Einflusses der jüngeren Tiere in Zukunft zu rechnen. Ausserdem ist anzunehmen, da die jungen Kabeljau des Skolpen-Gebiets noch nicht alle marktfähige Grösse erreicht haben, dass deren Menge in den Fängen auch hier zunächst noch zunehmen wird.

Im Murman-Gebiet sind die Verhältnisse am wenigsten klar, da häufige Veränderungen vorkommen; im allgemeinen ist der Kabeljaubestand im Herbst sehr ähnlich dem von Skolpenbank. Im Frühjahr ist er ziemlich wechselnd, zeigt aber meistens ein Überwiegen der kleineren Tiere, die ja dann in grosser Menge, meist allerdings von noch geringerer Grösse als in den deutschen Fängen, als "Loddetorsk" von der norwegischen Küstenfischerei erbeutet werden.

Beim Schellfisch liegt das Schwergewicht stärker auf den älteren Längen. Fische von 60—70 cm. ziehen im Spätsommer in ziemlich geschlossenen Schwärmen in das flache Kanin-Gebiet, und in der Zeit des ausgehenden Winters lässt sich ihre Rückwanderung längs der Murmanküste aus den Fängen der Fischdampfer gut erkennen. Die im Frühjahr an der Finnmarken- und westlichen Murmanküste gefangenen Schellfische zeigen fast genau die gleiche Längenzusammensetzung wie die im Herbst und Winter bei Kanin gefangenen. Kleine Schellfische erscheinen im Bereich der Fischerei im Sommer und Herbst an den äusseren Rändern der Flachwassergebiete, in grösster Zahl am westlichen Murman, ausserdem auch auf Skolpenbank und bei der Bäreninsel.

Die ausgeprägte Neigung zur Schwarmbildung beim Schellfisch bewirkt, dass die Messungen oft überraschend genaue Übereinstimmungen in der Längenzusammensetzung ergeben; die starken Wanderungen veranlassen im Gegensatz aber häufig sprunghafte Veränderungen, die die Sicherheit der Schlussfolgerungen stark beeinträchtigen.

Im Laufe der fünf Beobachtungsjahre sind hier verhältnismässig wenig Veränderungen eingetreten. Die für die Fischerei wichtigsten, die "Kanin-Schwärme", haben fast die gleiche Längenzusammensetzung behalten, nur deutet sich der jährliche Zuwachs durch eine Verlagerung des Kurvengipfels von Jahr zu Jahr um wenige Zentimeter an. Gerade diese Unveränderlichkeit aber gibt zu der Befürchtung Anlass, dass diese Schwärme demnächst ihrer Laichreife entgegen gehen und im Zusammenhang damit das Gebiet verlassen werden, genau wie es 1931 beim Kabeljau der Fall war. Damit würden sie der Fischerei wohl grossenteils verloren gehen, denn es scheint, dass der grosse Schellfisch nirgends im Bereich der Fischerei in grösseren Mengen vorkommt. Dies bleibt abzuwarten.

Einen allerdings nur geringfügig ansteigenden Anteil jüngerer Tiere mit Längen um 50 cm. weisen diese Schwärme seit 1931 auf, nachdem schon seit 1929 in den westlichen Randgebieten gelegentlich grössere Mengen, meist noch etwas kleinerer Schellfische erbeutet wurden. Dies ist also die neue Welle, die derjenigen beim Kabeljau parallel läuft, obwohl noch durch Altersbestimmungen nachzuweisen sein wird, dass es sich um die gleichen Jahrgänge handelt. In so grosser Menge, dass sie den vermuteten zukünftigen Verlust der älteren Tiere einigermassen werden ausgleichen können, hatten diese jungen Tiere erst 1933 zum ersten Mal. Da der Kurvengipfel ziemlich beständig $<$ 50 cm. bleibt, ist anzunehmen, dass der grösste Teil dieser kleinen Schellfische auch jetzt noch nicht marktfähige Grösse erreicht hat (was einige Beobachtungen an Bord von Fischdampfern auch bestätigt haben); ihr Wert für die Fischerei ist also noch weit vom Höhepunkt entfernt, sodass die Aussichten für die Zukunft ziemlich gut sind, selbst wenn die Abwanderung der alten Jahrgänge ein vorübergehendes Sinken der Fangerträge veranlassen sollte.

Die Anlandungsstatistik bestätigt diese Ergebnisse der Marktuntersuchungen vollauf. Zweckmässig unterscheidet man hier Fangperioden, beginnend am 1. Juni und endigend am 31. Mai des folgenden Jahres. Für die Fangperiode 1933/1934 liegen z. Z. nur unvollständige und vorläufige Zahlen vor.

Der Wechsel in den Fischereiverhältnissen zeigt sich in der Anlandungsstatistik vor allem durch veränderte Anteile der Marktsorten. Die kleinste Sorte III erreichte beim Kabeljau 1932/33 ihren Höchstanteil mit 30 % gegen nur 1 % bis zum Jahre 1929. 1933/34 waren die jungen Kabeljau bereits soweit herangewachsen, dass sie in die nächst höhere Marktsorte II übergingen, deren Anteil nun von 25 % 1929/30 auf etwa 50 % 1933/34 stieg. Die bisher weitaus vorherrschende Marktsorte I tritt also zur Zeit ziemlich zurück.

Beim Schellfisch ist die Veränderung — aus den oben genannten Gründen — weniger stark; der Anteil

er kleinsten Sorte III stieg nur von 2 % 1929 auf wa 12 % 1933/34.

Besonders wichtig ist ferner die Feststellung, dass e Fischerei den veränderten Verhältnissen Rechnung tragen hat, indem sie die jeweils günstigsten Gebiete ufgesucht hat. Seit 1930 wurde in steigendem Masse ei der Bäreninsel gefischt. Da dies mit den geschilerten Veränderungen der Fischbestände des inneren arentsmeeres unmittelbar nichts zu tun hat, so wird mit der Vergleich allerdings etwas unsicher. Die scherei bei der Bäreninsel erbringt grosse Mengen abeljau, dagegen nur wenig Schellfisch, und sie hat her bewirkt, dass der bisher in dem Gebiet an der itze stehende Schellfisch jetzt vom Kabeljau überoffen wird. Auch die Abnahme des mittleren Schellchertrages je Fangreise ist im wesentlichen in der ärkeren Befischung dieses an Schellfisch armen Getes begründet. Zweckmässig wird daher, obgleich e Bäreninsel an sich als ein Teil des Barentsmeeres ufzufassen ist, das innere Barentsmeer, d. h. das te Fanggebiet, auch für sich betrachtet. Es ergeben h folgende mittlere Fangmengen in 1000 kg. je angreise:

Parallel mit dem steigenden Anteil des Bäreninsel-Gebiets ab 1930 sehen wir also die Ausbeute der Kanin-Gegend, die bis 1929 für die Fischerei doppelt so grosse Mengen von Fischen lieferte als alle anderen Teilgebiete zusammen, stark sinken. Die Ursache war der Rückgang des Kabeljauertrages. 1933/34 scheint sich darin wenig geändert zu haben (genaue Zahlen fehlen zur Zeit noch); einer geringfügigen Zunahme des Kabeljau steht ein verhältnismässig erheblicher Rückgang der Schellfischerträge gegenüber, ob dieser schon als die vermutete Abwanderung der grossen Schellfische infolge Reifwerdens (s. oben) aufzufassen ist, bleibt zunächst allerdings noch unsicher.

Im ganzen sehen wir jedenfalls, dass das Minimum der Kabeljauerträge bereits überschritten ist; es fällt für das innere Barentsmeer in das Jahr 1931/32, da ja die neue Welle kleiner Kabeljau ab 1932 sehr stark in Erscheinung trat. Die Eröffnung der Fischerei bei der Bäreninsel konnte indessen dies Minimum in glücklicher Weise weitgehend ausgleichen. Der Schellfisch hingegen zeigt im letzten Jahr einen beträchtlichen Rückgang, dies insbesondere im inneren Barentsmeer, sodass wir zunächst noch mit einem weiteren Rückgang der Schellfischanlandungen zu rechnen haben.

ab. 1.

ngperiode	1929/30		1930/31		1931/32		1932/33		1933/34	
	Kabelj.	Schellf.	Kabelj.	Schellf.	Kabelj.	Schellf.	Kabelj.	Schellf.	Kabelj.	Schellf.
urman	15	31	9	37	18	27	20	26	?	(20)
olpen	25	18	19	25	17	19	39	19	(37)	(20)
anin	22	41	17	50	14	44	13	49	(15)	(30)
neres Barentsmeer	22	35	17	42	15	37	23	36	(25)	(28)
äreninsel	—	—	53	9	63	10	57	11	(47)	(10)
Zusammen	—	—	19	39	27	30	33	28	(35)	(23)

Der %-Anteil der einzelnen Teilgebiete an der esamtfischerei war folgender:

ab. 2.

ngperiode	1929/30			1930/31			1931/32			1932/33		
	Reisen	Kabelj.	Schellf.	Reisen	Kabelj.	Schellf.	Reisen	Kabelj.	Schellf.	Reisen	Kabelj.	Schellf.
urman	15	11	14	14	6	13	9	6	8	13	8	12
olpen	21	23	10	23	23	15	15	9	9	21	25	14
anin	64	66	76	55	49	70	50	26	75	35	13	61
neres Barentsmeer	100	100	100	92	78	98	74	41	92	69	46	87
äreninsel	—	—	—	8	22	2	26	59	8	31	54	13

II

THE COD OTOLITH AS A GUIDE TO RACE, SEXUAL DEVELOPMENT AND MORTALITY

BY

GUNNAR ROLLEFSEN, Bergen

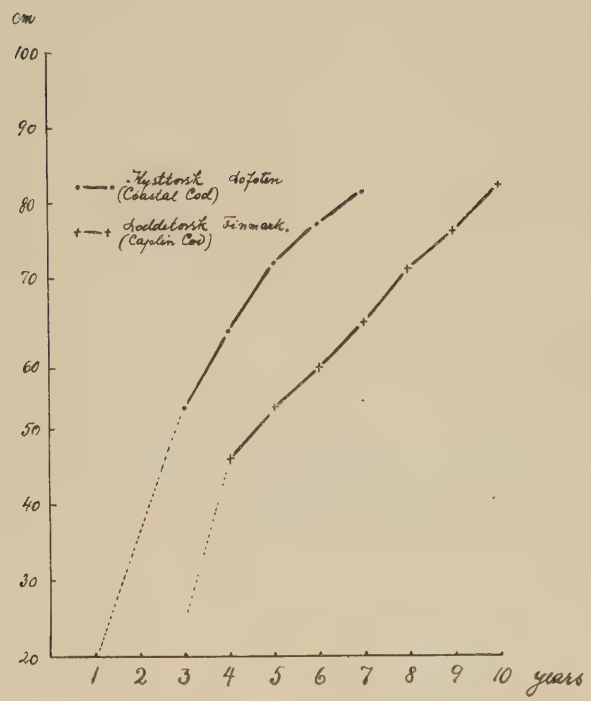


Fig. 1. Growth of two different Types of Cod.

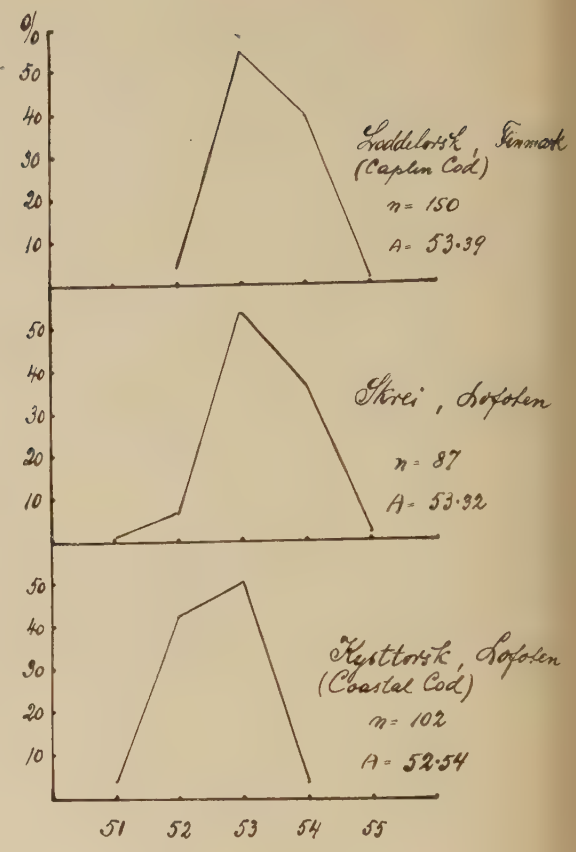


Fig. 3.

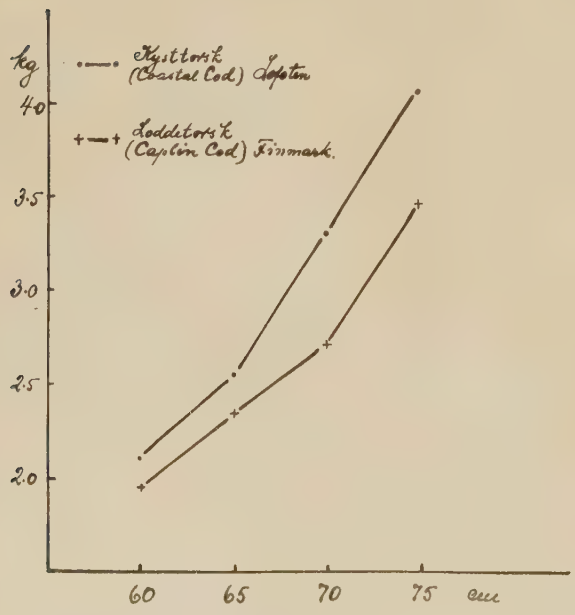


Fig. 2. Length and Weight (approx.) for two different Types of Cod.

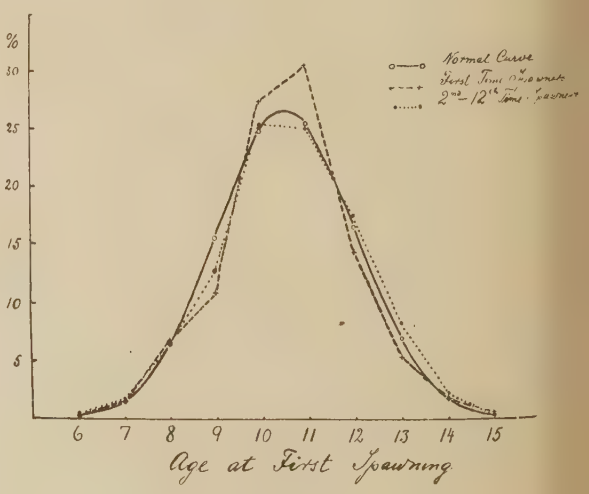


Fig. 4.

a preliminary publication "The Otoliths of the od" (Fiskeridir. skr., vol. IV, No. 3), the in- gations of the cod's otoliths have been dealt . It is pointed out that the outer zones in a great y of the mature "skrei" otoliths differ somewhat the inner zones, in that they are smaller and hyaline parts frequently more distinct and der than the opaque parts. Usually they occur arying numbers, but are never observed alter- g with wide zones.

As such narrow outer zones have never been ved in young unripe "loddetorsk", but are nt in some 60 % of the mature "skrei", it seems ral to connect the appearance of such zones maturity, and to explain them as spawning s.

is supposition (i. e. that the number of such w outer zones denotes the number of spawnings rmed) has led to the conclusions quoted below, on the material to hand:

That the "skrei" may attain maturity from the o the 15th year.

That the greatest number attain maturity in 10th and 11th year.

That they spawn every year after having ed maturity.

That those spawning for the first time make out 40 % of the stock on the spawning ground.

That the spawning classes are reduced in number out 35—40 % for each spawning.

That the so-called "gjelltorsk" is a large unripe, ot sterile, fish (8—15 years old).

That the attainment of maturity and the ing reduces the rate of growth considerably.

s applies to the stock of "loddetorsk" and " only (the Arcto-Norwegian Cod Stock, —).

rom the material hitherto collected of cod ging to the coastal stock, it appears that those ations grow quicker than the "loddetorsk" and " and that they reach maturity at a much age. Whether we consider the coastal cod the "skrei" as two races, or whether we explain ifferent characters as due to growth under nt conditions of life, it is equally important able to separate the coastal cod from the torsk" and the "skrei", where they appear , and to examine the two kinds individually. is not the growth rate only, and the early rity, which distinguish the coastal cod; its er of vertebrae is lower than that of the "skrei" loddetorsk", and its weight at the same size considerably greater. Fig. 1 shows the average length of the various age-groups of the coastal cod and the "loddetorsk", Fig. 2 shows the average weight of the various centimetre classes, and Fig. 3 the number of vertebrae of the "loddetorsk", "skrei" and coastal cod.

In the "Otoliths of the Cod" it was maintained that the otoliths of the coastal cod differed from those of the "loddetorsk" and the "skrei" in a very characteristic way, both in external appearance and in the structure of the zones.

Among the shoals of "skrei" at Lofoten a mixture of cod with the same type of otoliths as that of the coastal cod is to be found, and it is of importance, when estimating the stock of "skrei", to be able to ascertain the proportion of such a mixture.

A sufficient amount of material of vertebrae of the coastal cod and "skrei" not yet having been collected from the mixture ordinarily occurring, an artificial mixture of a "skrei" sample and a sample of a coastal cod was made, in order to determine the value of the otolith-type. The sample was mixed in a random way and each individual was distinguished only by a number. The result of the sorting out was that the individuals with otoliths of the type of the coastal cod had an average vertebrae count of 52.56, while those of the "skrei" type had 53.32. In the original samples the "skrei" showed 53.32 and the coastal cod 52.54. There is, therefore, every probability of an objective connection between the number of vertebrae and the type of otolith.

Previous investigations give us information as to the area of distribution of the Arcto-Norwegian cod stock. We know that the appearance of the young immature "loddetorsk" is limited to the Barents Sea and that the mature "skrei" has its main spawning place off the Norwegian coast.

We may notice a good year-class appear in Finmark and find it later in the shoals of "skrei", but to the best of my knowledge the question has never been settled as to what is decisive for the cod reaching maturity, nor the question as to the extent of maturity occurring among individuals of one and the same year-class at different ages. The last question, as well as the question of decrease within the stock of "skrei", is of great practical interest, and it will be evident from what follows, that the pointing out of spawning zones is of great importance to the solving of these two problems, viz. the recruiting of the stock of "skrei" as well as the decrease of same. Even if there is no absolutely decisive proof of the theory, that the narrow outer zones of the otolith are actually

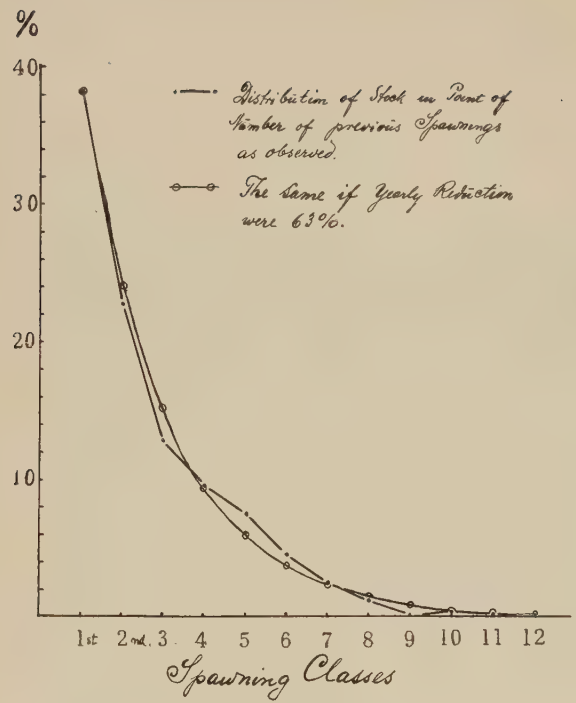


Fig. 5.

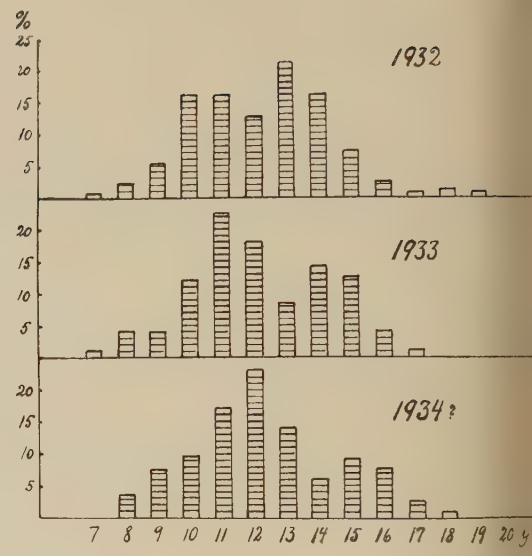


Fig. 7.
The observed Age-composition of the Skrei, 1932 1933, and calculated Forecast for 1934.

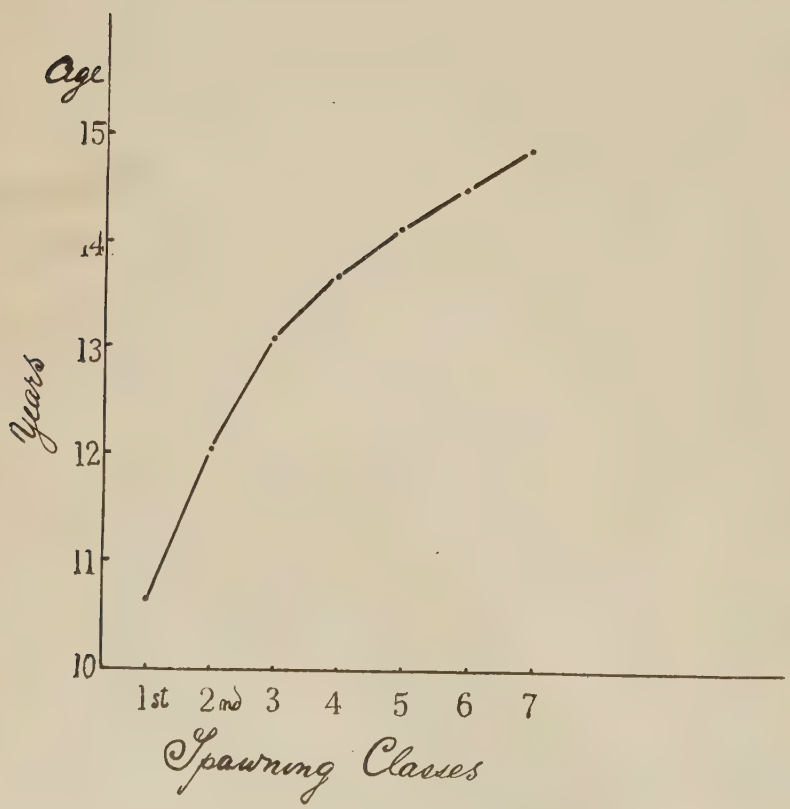


Fig. 6. The average Age of the Spawning Classes.

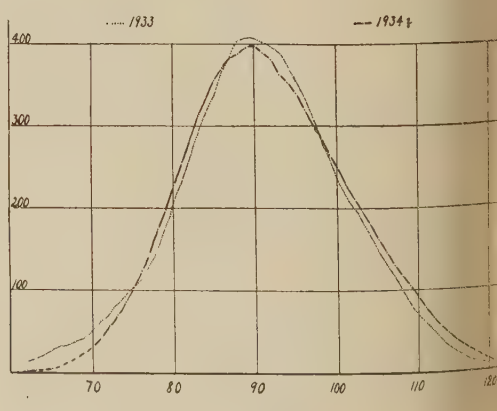


Fig. 8.

wning zones, there is, however, much that tends prove that the explanation is correct; it seems sonable therefore to base the following conclusions this supposition.

n some 60 % of the "skrei" narrow spawning es in the otolith are found in larger or smaller nbers. The other 40 % have no such narrow zones. se individuals are then to be regarded as first-e spawners, while individuals with one narrow er zone are distinguished as second-time spawners, so on. If the material is arranged according to age of the individuals at their first spawning, it ound to be distributed as indicated in Fig. 4.

very small number has reached maturity at the of 6 years, but the proportion increases every year l the 10th. The height is attained in the 11th r, but decreases thereafter at a rate corresponding hat of the increase.

Ve find that the average spawning age of the "skrei" $0^1/_2$ years and that 50 % of the individuals have hed maturity during their 10th and 11th year. comparison, the contour of the normal distrib-n with similar standard deviation and a similar ber of individuals has been drawn.

his distribution of the individuals with an ap-ntly more frequent occurrence of maturity at 10th and 11th year, is probably not due only to attainment of maturity. Maturity can be reached uch varying ages as from the 6th to the 15th , and the fish, therefore, which are late in sexual development are to a greater extent e to be decimated by the factors which affect stock of "loddetorsk" than those which reach rity at an earlier age.

the "skrei" attains maturity according to ite rules, and if the factors, which serve to nate them, are equally strong every year, the te of each year-class to the first-time spawners occur according to a regular scale. This scale l be calculated by means of the distribution of time spawners and the ages of these individuals, ghout a long period. Such series of observations not available, but the age distribution of the spawning classes may be taken into con-lation in order to form an idea of this scale 4).

nsidering the shoals of spawning "skrei" as con-g of first-time spawners, second-time spawners, it will be seen that these groups appear to in regular proportions to one another.

pposing that the stock of "skrei" for a number ars did not suffer any loss, a number of second-spawners equal to that of first-time spawners g the first year would appear, and again the same number of third-time spawners as there were second-time spawners in the previous year, and so on. In other words, each spawning class would be numerically equal; this is of course subject to the supposition that the "skrei" spawns every year and that the total spawning area is taken into consideration. We find, however, that the spawning classes appear in relatively smaller numbers the older the individuals grow. A constant decimation takes place, and each spawning class generally amounts to about 63 % of the previous one (Fig. 5).

This reduction of the spawning classes in relative numbers is explained as the decrease in the "skrei" stock.

If the decrease within each spawning class were due only to causes that worked equally strongly both on the big and small individuals, and on the old as well as the young ones, the relative age-distribution within the spawning classes should be constant as long as they exist.

We notice, however, that the older the spawning classes grow, the more the younger components dominate.

As shown in Fig. 6, the difference in the average ages of the spawning classes decreases with the age; probably this is due to the fact that the older individuals of the spawning class, by natural mortality, are subject to a heavier decimation than the younger ones.

The material which provides the basis for these considerations consists of about 1,000 individuals collected at Lofoten during 1932 and 1933. If so much importance is attributed to such a comparatively small material, the reason is that it shows a very regular distribution, and because the material from two different years shows a distinct parallelism.

If the increase and decrease of the stock of "skrei" occur in the way here indicated, we should be able to calculate the average distribution of the coming year from that of the previous year.

Such calculation, however, rests at present on very insufficient material, although the method, generally speaking, may be regarded as correct. It is, however, interesting to find out how closely the calculated and real age-distribution agree, and for this reason the distribution for 1934 has been calculated; the result of this calculation is shown in Fig. 7. Based on this age-distribution, the length distribution may then be calculated (Fig. 8).

This length distribution applies to the "skrei" only. As regards Lofoten, it must also be taken into consideration that the coastal cod will have a certain effect, and as the occurrence of littoral fry seemed to prove that the year-class 1930 is comparatively rich, it is very probable that, in 1934, a comparatively large addition of coastal cod of 60—70 cm. will occur.

III

STATISTICAL ANALYSIS OF THE NORWEGIAN HERRING POPULATION

BY

PER OTTESTAD, Oslo

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Introduction.

The discovery that the age of fish could be determined by counting the number of winter rings the scales and otoliths introduced a new method work in marine biological research. From that ment it became possible to apply to the study of life history of the various kinds of fish the methods ated and employed by the science of human ulation. In a lecture by Professor JOHAN HJORT ore the International Council in 1907 (HJORT 1908) new programme was introduced in the following ds:

To make my ideas clearer, I will proceed to draw comparison between this Fishery Research and a ience which is much more generally understood. mean the science of Vital Statistics.

In all exposition of the science of vital statistics, ere are three prominent features which attract r chief consideration:

1. Birth-rate. 2. Age-distribution. 3. Migration.

is customary to study these questions by help what are called representative statistics. A certain mber of individuals are selected, who are supposed stand for the mass of people, and attention is ected to them. We ascertain from this source their erage length of life, their wanderings, their increase decrease, and whether sickness, war, disaster, or igration plays any appreciable part in reducing the ulation.

It seems at first sight a bold suggestion to propose dying the fish-supply on lines like these. A ulation can be counted; but who knows how ny fishes are in the sea? And yet it appears to a project, big with possibility, to regard the coveries of fishery research from a similar standnt to what has been adopted in the science of vital tistics. As a matter of fact these two biological nces have much in common. Both are engaged studying living organisms with their probabilities ife and death. And by comparing fishery research h the older and surer science, its shortcomings l discoveries will be even more clearly brought view."

this way a new programme of work was introd. the lines of which have been followed, generally king, in fishery research ever since. The programme ded, however, one far-reaching aim, namely to in such a conspectus and knowledge of the life history of the various kinds of fish, with their probability of life and death and their migrations, that it would be possible to establish a reliable control of the stock. Posterity has shown that it has been possible not only to follow this programme, but to attain the desired end.

The first investigations along these new lines at once directed attention to ideas of a totally different nature from those with which we are familiar in the study of human populations. The renewal of a human population by birth is nearly constant from year to year. In a population of fish, however, the recruitment is subject to great fluctuations (HJORT 1914). The numbers of individuals in the various year-classes differ to such an extent that the calculated ratio of the numbers of individuals in two year-classes of the Norwegian herring has actually been put at 1:30 (see HJORT, JAHN and OTTESTAD 1933). The reason for these violent fluctuations is mainly the enormous mortality during the first stages of life.

Moreover a key to elucidate the causes of the well-known fluctuations in the yield of the fisheries was found in this way. When, for instance, a numerous year-class enters the shoals of Norwegian spring-herring, good yields can be expected for a number of years.

The study of migration plays an important part in the realization of Dr. HJORT's programme. The study of this phenomenon is comparatively simple when we are dealing with some kinds of fish (cod, for instance) which can be marked and recaptured. With other kinds of fish, like the herring, which does not survive the strain of marking, we are confronted by many difficulties in our study of migration. In the latter case it is necessary to tackle the problem by quite different methods, and various proposals have been discussed as a basis for the study of the migrations of the herring.

JOHANSEN (1927) maintains that the study of the number of vertebrae and other anthopometric characters would enable us to throw light upon this important question. LEA (1929_1) emphasizes the different types of scales found in different waters. Interesting in this connection, is his statement that the scales of herring from north Norwegian coastal waters have very sharp-cut winter rings as compared with scales of herring from more southern waters and

from the open sea. STORROW, HODGSON, LEA and others are of the opinion that the rate of growth can be used as an indication in the study of herring migration.

It is well known that the different areas of the sea are inhabited by different growth-types of herring (see HJORT 1914). The question is, therefore, whether studies of growth will enable us to characterize the herring of different localities, thus affording a means of studying migration. It is, of course, impossible to say whether the result obtained by this method will be successful in any particular case. It depends, naturally, on the general conditions. This also applies to indications such as the number of vertebrae, type of the scale etc. These characters — including the number of vertebrae (RUNNSTRØM 1933_2) — are all highly dependent on environmental conditions and will accordingly be characteristic of the various biological groups of herring. In each case it seems obvious that all the characters should, if possible, be considered, as one of them may supplement another.

The present paper does not, in the first place, aim at a final solution of a definite problem. The main object has been to try to find out whether the study of the growth of the herring will give us a more complete understanding of its life-history. In our opinion a theoretical discussion of such a method cannot lead to profitable conclusions. In the present case one must make an attempt to apply the method, in other words to find out empirically how far one can get by this means. The methodical analysis is, therefore, the chief aim of this statistical study.

The result of the investigation undertaken is that, as regards the Norwegian herring, the study of the growth gives a good basis for the elucidation of migration problems. It has been proved that whenever a sample of Norwegian herring has been examined, certain qualitative signs have made it possible to distinguish groups whose mean growth differs. Further, it has been proved that only a part of the immature young fat-herring in the coastal waters of northern Norway join the shoals of the South Norwegian large and spring-herring, a fact which proves that two or more Norwegian stocks of herring exist. This result coincides extraordinarily well with the investigations made with regard to spawning areas in recent years. By charting the occurrence of newly hatched herring larvae RUNNSTRØM (1933_1) has shown that the spawning of herring is not limited to the coastal districts where spawning herring (spring-herring) are caught.

The material at our disposal has largely been borrowed from the Fishery Directorate, Bergen, by courtesy of Dr. RUNNSTRØM. Further, we have utilized the tables published by HJORT and LEA (1910).

During my work I have received much valuable assistance. Mr. TH. RASMUSSEN has calculated a great many of the growth-tables and various hints have been given me by Dr. SVEN RUNNSTRØM, Mr. OSCAR SUND, Dr. HJ. BROCH and Dr. J. T. RUUD. I avail myself of this opportunity to express my cordial thanks to them all. Special thanks are due to Professor Dr. JOHAN HJORT for permitting me to do this work in his laboratory, and for his never-failing interest in my investigation.

CHAPTER I

Statistical methods.

A statistical analysis of a stock of fish must be based on the representative method of investigation. It is not feasible to examine every single individual of the stock, but a certain number only. The question arises, therefore, whether this number is representative of the whole stock which is the object of investigation; in other words whether the characters of the sample can be directly transferred to the entire stock.

In statistics of human populations the representative method is also used to a great extent. In such investigations it is possible personally to choose the units and to make this choice in such a way that the sample becomes representative of the whole mass of units. The choice can be made deliberately. This, however, cannot be done when we are dealing with a stock of fish. In such cases we must be satisfied with samples about which we do not know beforehand whether they are representative of the entire stock or not. The task is particularly difficult when we are concerned with the Norwegian herring. In this case we have to be satisfied with samples from the coastal waters during the season in which the herring approaches the coast for the purpose of spawning or during its food-migrations.

In the case of such a typical shoal-fish as the herring, the estimation of a sample as representative of the stock has two aspects. First we must ascertain whether the sample is representative of the shoal from which it is taken. The next question is to decide whether the sample is representative of the entire stock or of the biological group of the stock from which the particular shoal is derived.

The experience gained in herring investigations proves that a large sample can be taken as very approximately representative of the shoal whence it is derived. The following example will illustrate this. Our material contains four samples of large-herring taken in the same locality and at nearly the same time (January 1915). The distribution according to age is given in Table 1. It will be seen from this Table

ble 1. Large-herrings from "Grip" 1915. Percentage number of individuals of the different year-classes.

te	Year-class												
	1911	1910	1909	1908	1907	1906	1905	1904	1903	1902*	1901	1900	1899
.....	1.1	3.2	1.6	3.2	2.7	3.2	12.4	61.1	5.4	3.8	1.6	0.5	—
.....	0.9	4.3	2.6	5.6	3.0	4.3	12.4	59.2	3.8	0.9	2.1	0.9	—
.....	—	2.5	2.5	7.9	4.5	4.5	14.0	54.5	4.1	0.8	2.9	1.7	—
.....	0.5	1.9	2.9	6.8	4.8	5.8	17.9	52.2	3.9	1.4	1.4	—	0.5

t a certain year-class is represented by a nearly al percentage number of individuals in all four ples, and further that just the same year-classes represented in each sample. The conclusion which y be drawn from this is, therefore, an important that a single sample only forms a sufficiently ct basis for ascertaining the age-distribution of individuals of the shoal. This will also be found apply to the growth. In Table 2 the mean yearly

ble 2. Mean values in cm. of t_1, t_2, t_3 etc. for the wth-type A of the year-class 1904 as large-herring ip 1915). N stands for the number of individuals examined.

e	t_1	t_2	t_3	t_4	t_5	N
.....	8.8	7.4	5.7	3.6	2.3	58
.....	8.8	7.3	5.9	3.6	2.4	54
.....	8.7	7.4	5.7	3.4	2.2	59
.....	8.8	7.6	5.8	3.6	2.1	54

ements in length are given for the growth-type A ined below) of the year-class 1904. It will be ced that the mean growth-rate is just the same ll four samples, and accordingly it is evident that of these samples only would have given a reliable representative idea of the growth of the group sidered.

s regards the second question, viz. whether a ple may be taken as representative of the whole k of fish, it has been found that caution is neces-. Experience shows, for instance, that during a vning season shoals which differ much in age-position, enter the coastal waters (see LEA 1929$_2$). ordingly, a study of a stock of fish first involves examination of single shoals, after which the task o make comparisons and thus obtain an idea of stock as a whole or of a minor biological group t.

he present investigation is to a great extent based n the application of statistical methods. As these hods are very elementary and do not differ rally from the statistical methods ordinarily , it is unnecessary to describe them. It would ; however, that certain methods, particularly which are based upon frequency functions, not always been correctly understood and used iological researches. This applies particularly to hods used when the object in view is to charac-e frequency-distributions.

hen a series of observations is under consideration, length measurements of a great number of fish, important to give this material, in itself unsurvey-able, a short description which is as complete as possible, or in other words, to represent the series of observations by a few quantities. If the observations are length measurements — as in the present paper — a preliminary survey of the material is obtained by arranging the observations in a frequency series as follows:

$$\begin{array}{l} x \;:\; x_1 \quad x_2 \quad x_3 \;\ldots\ldots\ldots\; x_n \\ H(x) : H(x_1)\; H(x_2)\; H(x_3) \ldots\ldots\ldots\; H(x_n) \end{array}$$

Here x denotes the length and $H(x)$ the number of individuals of this length. The first summary expression of this series is obtained by means of the arithmetical mean:

$$m = \frac{\Sigma H(x) \cdot x}{N}$$

in which $N = \Sigma H(x)$. This quantity cannot, however, by itself give a complete characterisation of the frequency series. In particular it cannot express the distribution of the individuals corresponding to the different values of the sign (length). More series of quantities (moments, semi-invariants etc.) have been introduced as a measure of this distribution, but these quantities will not be discussed here. In biological investigations the quantity generally used for this purpose is the standard deviation, the value of which is calculated by the formula:

$$\sigma = \sqrt{\frac{\Sigma H(x) \cdot (x-m)^2}{N}}$$

Like most of the statistical quantities the standard deviation — as a measure of the distribution — has been introduced on certain assumptions concerning the statistical series. The standard deviation, in itself, can tell us nothing about the distribution. If it is proved, however, that the statistical series in question can be approximately replaced by a certain frequency function, and if the significance of the standard deviation as a measure of the distribution for this function can be fixed once for all, the standard deviation can be used as a measure of the distribution. In dealing with length measurements, experience shows that the statistical series may frequently be approximately represented by the exponential frequency function:

$$f(x) = \frac{1}{\sqrt{2\pi} \cdot \sigma} \cdot e^{-\frac{(x-m)^2}{2\sigma^2}}.$$

This does not, however, justify the practice, often met with, of taking it for granted that the statistical series is exponential, and accordingly using the standard deviation as a measure of the distribution. It is absolutely necessary to ascertain in each case whether the agreement with the exponential frequency function really exists. If this agreement can be proved, the significance of the standard deviation as a measure of the distribution of the series is given by the function itself or by a table of which we reproduce a summary (Table 3). In this table l denotes the deviation from

Table 3. See text.

l	S	l	S
$0.5\,\sigma$	0.383	$2.5\,\sigma$	0.988
$1.0\,\sigma$	0.683	$3.0\,\sigma$	0.9973
$1.5\,\sigma$	0.866	$3.5\,\sigma$	0.9995
$2.0\,\sigma$	0.954	$4.0\,\sigma$	0.99994

the mean and S the fraction of the total number of units (N) which do not deviate from the mean by more than the corresponding l. It will be seen that about $^2/_3$ (0.683) of the units are found within the limits $(m - \sigma)$ and $(m + \sigma)$ and practically the total number of units within the limits $(m - 2.5\,\sigma)$ and $(m + 2.5\,\sigma)$.

When dealing with observations — including length measurements — one cannot expect the frequency series obtained to be approximately represented by the exponential frequency law until the material has been separated into groups according to certain signs. As a rule the series which stand for the different groups are characterized by different values of the mean and of the standard deviation. In the case of length measurements a lack of agreement between the statistical series and the exponential law suggests that the material has not been sufficiently divided up, and the problem then arises of finding signs which will render possible a further sub-division. Hence it will be understood that it is highly important to frame a method of proving whether or not a statistical series can be approximately represented by the exponential frequency law. Such a method has been introduced by GULDBERG (1931). We are given a statistical series:

x :	0	1	2	.....	k
$H(x)$:	$H(0)$	$H(1)$	$H(2)$	.....	$H(k)$

First the mean and the standard deviation (m and σ) have to be calculated. The criterion indicating that the exponential frequency function can be substituted for the statistical series is that the approximation coefficient

$$\alpha\,(x) = \frac{\psi\,(x)}{m^2/\sigma^2}$$

in which

$$\psi\,(x) = \frac{H\,(x+1)}{H\,(x)}\,(x+1) + \frac{m - \sigma^2}{\sigma^2} \cdot x$$

is constant for all the values of x and approximately equal to unity, and further that $m = 2 \cdot \sigma^2$ (approximately). OTTESTAD (1933) gives an example showing the simplest method of doing these calculations.

The great aim of biological research is to isolate main causes by the method of sub-division. In our opinion it is just for this analysis that GULDBERG'S method is most important. In dealing with such observations as length measurements, experience shows that frequency series resulting from a preliminary analysis of the material rarely agree with the exponential frequency function. It shows also that this is as a rule due to the sample being composed of two or more groups, the units of which are distributed about different means. In such cases a sub-division of the material results in two or more frequency series which agree well with the exponential frequency law. On the other hand, such agreement with the exponential frequency function does not justify the conclusion that the material in question cannot be further divided into groups of units distributed about various means. In cases, however, where the sub-division has been carried as far as possible, agreement with the exponential frequency function might be taken as an indication that any main groups which may exist have been isolated.

Finally it should be mentioned that the standard deviation plays an important part in fixing the limits of variation of the arithmetical mean. Like the single observation, the mean is, in the statistical sense, a variable quantity. The standard deviation of the mean is given by the formula:

$$\mu = \frac{\sigma}{\sqrt{N}}$$

in which σ is the standard deviation of the frequency series from which the mean in question is calculated. The significance of the standard deviation as a measure of the distribution in the series to which the mean belongs, is given by the exponential frequency function or by the table reproduced above (Table 3). For it has been proved that a polynom, and particularly the polynom:

$$g = \frac{o_1}{n} + \frac{o_2}{n} + \frac{o_3}{n} + \ldots\ldots\ldots + \frac{o_k}{n}$$

tends to take the form of the exponential frequency function, even if the individual terms do not follow this law. This peculiarity of the polynom is mainly due to the large number of its terms.

As the arithmetical mean is a variable, not a constant quantity, the question often arises whether the difference between two means which refer to two samples of observations, should be eliminated or reversed to the opposite way if new observations are collected. If the mean in one sample is m_1 and in another sample m_2, and the corresponding standard deviations of these means are μ_1 and μ_2, the standard deviation of the difference between these two means

is equal to $\sqrt{\mu_1^2 + \mu_2^2}$. It has been proved that if the difference $(m_1 - m_2)$ is four or more times as great as its standard deviation, the mean in the first sample (m_1) is due to other main causes than the mean in the second sample (m_2). Caution is necessary when applying this rule, because — particularly when few observations are available — the agreement between the frequency distribution to which the mean belongs and the exponential frequency function depends upon the number of observations. The conclusion, however, that two means are due to quite different causes, can often be reached on other grounds. Later on mention will be made of several cases in which we have been able to make repeated collections of observations by securing several samples of one and the same shoal of herring or of the same biological group of herring. In these cases it is possible to observe whether the values of the difference which is being studied, show in one or more cases opposite tendencies to the values in other cases.

CHAPTER II

On the relation between the growth of the herring and that of its scales.

The first investigations of the growth of herring, after the discovery of the method of determining the age by counting the winter rings of the scales, were based upon the assumption that a proportional relation exists between the growth of the fish and that of its scales. This hypothesis was a very natural one, but at the same time it was clearly understood that it was necessary to prove the correctness of it, and accordingly an investigation of this matter was undertaken by Lea (1910). We shall revert below to the method which was used for the purpose. Since these preliminary investigations, however, many papers on this question have been published. These contributions have generally endeavoured to prove or disprove the correctness of the supposed proportional relation; and although most experts who study the growth of herring still base their researches upon this hypothesis, the general impression is that the relation in question is not definitely known. Naturally, the same problem arises with regard to other kinds of fish as well.

It must be admitted that it is no simple matter to prove the correctness of the hypothesis that the relation between the growth of the fish and that of its scales is proportional. But unquestionably most experts have made the matter appear more difficult than it actually is. Almost everybody who has gone into the matter, has identified the solution of the problem with the study of the correlation between the length of the fish and a specially defined linear dimension of a certain scale. This method cannot, in our opinion, lead to correct conclusions, nor have the mathematical methods employed been correctly understood. Lea (1933) has discussed some of these matters, but he still seems to be of the opinion that the relation between the growth of the fish and that of the scales has to be studied by means of mathematical methods of correlation. We cannot agree with this opinion, and later on we shall try to explain why. First of all, however, a clear definition must be given of the statement that the growth of the fish is proportional to the growth of its scales.

In the following discussion y denotes the length of the fish and x a linear dimension of the scale. Both quantities are functions of the age (t), expressed by:

$$y = f(t) \text{ and } x = p(t).$$

If a proportional relation exists between the growth of the fish and that of its scale, this fact is in mathematical symbolic language expressed by the equation:

$$f(t) = k \cdot p(t).$$

Evidently, the various individuals do not grow at the same rate, i. e. $f(t)$ is different in the case of different individuals (for instance in a group of herring). This also applies to $p(t)$. Provided that the above equation is correct, k must be a constant quantity when it concerns a single individual, but a variable quantity in a group of individuals. Some material which gives an idea of the variation of k has been published by Lea (1910). k denotes the ratio of the length of the fish to the particular scale-dimension at any age. Table 4 shows that the value of k varies between 25 and 32.

Table 4. Frequency distribution of the proportion y/x for 218 spring-herrings from the west coast of Norway. The material taken from Lea (1910) Table I, Herrings with 6 winter-rings.

y/x	25-26	26-27	27-28	28-29	29-30	30-31	31-32
Frequency ...	6	16	56	77	40	15	8

The problem then arises how an investigation should be planned with a view to ascertaining whether the relation between the growth of the fish and that of its scales is proportional. Does any possibility exist, as has been argued by many investigators, of reaching a correct conclusion by investigating the correlation between the length of the fish and a certain linear dimension of the scale? This question having also a bearing upon other problems than those here considered, we may be allowed to go further into the matter.

A quantity observed is variable, in a statistical sense, if the value of it varies from unit to unit in a sample of individuals. Thus, the length of fish is a variable quantity because it differs from individual

to individual. The individual values, however, can generally be grouped with a certain regularity about a certain value: the mean.

If corresponding values of two such quantities (x and y) are observed, it is very often desirable to find out whether these quantities are correlated. An investigation will then try to ascertain whether the values of the quantities deviate from the respective means in the same or in an opposite direction, and with relatively equal values. A preliminary grasp of this question is obtained by working out a correlation-table. Thus Table 5 shows the number of the corresponding values of the total length of herring and a certain linear dimension of the scale, viz. the number of individuals of equal length and with equal scale dimension. The material for this table has been derived from LEA (1910). It will be seen that a certain relation exists between the quantities considered; thus the large herring have bigger scales than the small ones. But it will also be seen that the correlation is not very close. The table is not suitable, however, for further investigations into this matter.

Table 5. Correlation between the length of the herring and that of the linear dimension of its scale. The data are taken from LEA (1910). — Table I, herrings with 6 winter rings.

Length of the herring (cm.)	Dimension of the scale 86-88	89-91	92-94	95-97	98-100	101-103	104-106	107-109	110-112	113-115	116-118	Total
25—26	1	1	1	1	—	—	—	—	—	—	—	4
26—27	1	5	3	9	2	—	—	—	—	—	—	20
27—28	—	3	4	23	11	8	7	—	1	—	—	57
28—29	—	1	7	12	19	19	12	5	2	—	—	77
29—30	—	—	—	3	7	18	11	8	—	—	1	48
30—31	—	—	1	—	1	4	2	2	—	1	—	11
31—32	—	—	—	—	—	—	—	—	1	—	—	1
Total...	2	10	16	48	40	49	32	15	4	1	1	218

Below we will consider some of the quantities generally used in biological studies of correlation. In the first place the so-called correlation-coefficient and the regression-lines must be mentioned. The correlation-coefficient is used for the purpose of measuring the degree of correlation between the two quantities in question, and, alas, it is often used in this way without any reservation. In reality there are very few cases in which importance can be attached to the correlation-coefficient as such a measuring quantity. No great familiarity with the theory of mathematical statistics is necessary to understand this. The correlation-coefficient, like other statistical quantities, is introduced with due regard to certain assumptions, and its importance as a measure of the correlation is obviously limited to cases where the empirical material conforms to these assumptions. The correlation-coefficient, calculated by BRAVAIS' formula, is deduced from the exponential frequency function with two variables, viz.:

$$f(x, y) = \frac{\sqrt{1-\varrho^2}}{2\pi\sigma\tau} \cdot e^{-\frac{1}{2}\left(\frac{x^2}{\sigma^2} - \frac{2\varrho xy}{\sigma\tau} + \frac{y^2}{\tau^2}\right)}.$$

Concerning the question whether this coefficient can be deduced from other frequency functions, we cannot express any opinion. The main point is, however, that it cannot be used as a measure of correlation unless the correlation table agrees well with one of the frequency functions from which the coefficient is deduced. Where measurements are concerned, the exponential frequency function has been found as a rule to be the only one applicable. If the two-dimensional distribution in question does not agree with the exponential frequency function, the correlation-coefficient may be calculated by BRAVAIS' formula, but in that case this quantity loses its fundamental importance. What methods should be used for the purpose of ascertaining whether there is any agreement between the frequency distribution (the correlation table) and the exponential frequency function will not be discussed here[1]). Only a few rules, which ought to be taken into consideration in analysing the statistical data before drawing up the correlation table, will be mentioned.

In the mathematical treatment of correlation problems the exponential frequency function with two variables plays a part similar to that of the exponential frequency function with one variable in the description of uni-dimensional distributions. The rules for the treatment of the observation-material are also similar in the two cases. When uni-dimensional distributions are considered, and the material contains measurement data, experience shows that the exponential frequency function with one variable may be substituted for the frequency series if the material is sub-divided to a certain extent. The same subdivision has usually to be made when studying the correlation between two quantities. If, for instance, the investigation especially concerns the correlation between the length of fish and a certain dimension of scale, a division of the material according to age is always necessary. This treatment, however, is not always sufficient, and a further analysis, according to certain qualitative signs, must be made. Not until such analysis has been carried as far as possible, should the correlation table be compiled and the

[1]) New methods for this purpose are at present being prepared. Cf. GULDBERG (1931) and (1933).

agreement with the exponential frequency function examined. If the agreement between the correlation table and the exponential frequency function has been proved, the correlation-coefficient can be used as a measure of the correlation between the two quantities considered.

In discussions of the correlation between the length of fish and a particular scale-dimension reference is often made to the so-called regression-lines. If the two quantities (x and y) the correlation of which is to be investigated, can take the values x_1, x_2, x_3, ... x_i, ... x_n and y_1, y_2, y_3, ... y_j, ... y_m respectively, the means of y can be calculated for each value of x from the correlation table. We will call these means $u_1(y)$, $u_2(y)$, $u_3(y)$, ... $u_i(y)$, ... $u_n(y)$ respectively; thus corresponding to $x = x_i$ the mean of y is $u_i(y)$. In this way a series of n numeral pairs appear which, in a rectangular coordinate system with x as the abscissa and $u(y)$ as the ordinate, may be represented by n points. Similarly, by means of the correlation table, the means of x corresponding to each value of y can be calculated. Calling these means $v_1(x)$, $v_2(x)$, $v_3(x)$, ... $v_j(x)$, ... $v_m(x)$, another series of m numeral pairs appears, which, in a rectangular coordinate system with $v(x)$ as the abscissa and y as the ordinate, may be represented by m points. Each of the two point systems lies on a curve, and the two curves thus drawn are known as the regression-lines. Sometimes these lines are straight and then we get the following equations:

$$u(y) = a \cdot x + c$$

and

$$y = b \cdot v(x) + d.$$

In some papers on the correlation between the length of fish and a linear scale-dimension, deliberations on the character of the regression-lines are often met with. In many cases these lines are curved, and this fact has been taken as a proof that the relation between the growth of the fish and that of its scales is not proportional. We shall go further into this matter. First, however, it is necessary to ascertain in what cases rectilinear regression may be expected. Here, too, we must take into consideration the characters of the correlation table as was done above in discussing the correct use of the correlation coefficient. There is no reason to expect rectilinear regression in the case here considered, unless the distribution (the correlation table) is exponential or may practically be considered so. But the correlation tables given in the literature for the length of the fish and the linear dimension of the scales are not exponential. In some cases, therefore, the curved regression lines are due to the material being insufficient, in others to the fact that the material is not sufficiently divided up, or to both causes.

As already mentioned, we are of opinion that the problem of the relation between the growth of the fish and that of its scales cannot be studied by examining the correlation between the length of the fish and a linear scale-dimension. We shall now revert to this question, and will imagine that we have a correlation table in which the length of the fish and a certain linear dimension of a certain scale are the two variable quantities (x and y). Further, we will suppose that the correlation table is exponential, that the correlation-coefficient is equal to unity and that the regression-lines are straight and identical.

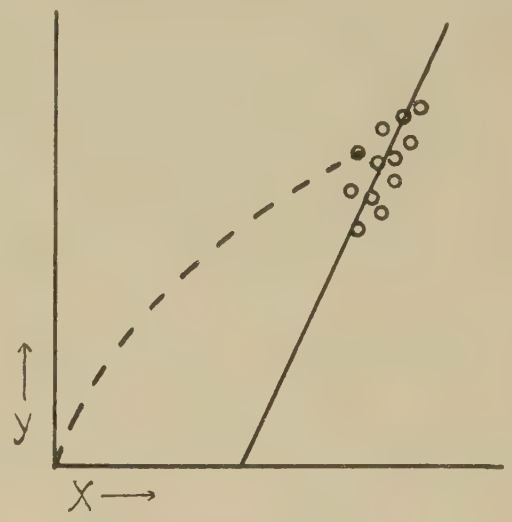

Fig. 1. X: length of the fish, Y: linear dimension of the scale. ———— regression line, — — — — — graphic representation of the function between the growth of the fish and that of the scale.

The regression-lines are, accordingly, given by the two following equations:

$$u(y) = a \cdot x + c$$
$$y = a \cdot v(x) + c$$

in which c indicates the point at which the lines cross the y-axis. If $c = 0$, the lines go through origo.

May this fact be considered as a proof that there is a proportional relation between the growth of the fish and that of its scales? It will be understood that the above-mentioned regression-lines only describe the relation, on the one hand, between x and the means of y corresponding to the various values of x, and on the other hand, between y and the means of x corresponding to the various values of y, within the group of fish to which the correlation table refers. It will also be understood that the line — whether straight or curved — illustrating the ratio between the length of a single fish and a certain scale-dimension at each stage of its life has no connection with this regression-line. We have tried to illustrate this by Fig. 1, in which the plotted points form what Lea (1933) calls a "point-cluster". The continuous line is the regression-line (or the two identical ones) while the broken line, which we have drawn curved (without thereby asserting that this is its actual character), represents the functional relation between the growth of the fish and the growth of its scale.

But, how to prove or disprove the correctness of the hypothesis? A correct method has to be found. The problem is considerably simpler with fish like the cod which can be marked and recaptured, than with other kinds, such as the herring, which cannot be marked. As regards cod, WINGE (1915) made an investigation which proved that the cod and its scales grew at the same rate, proportionally, in the interval between marking and recapture.

As regards herring, a similar investigation is not possible because this fish does not survive the strain put upon it by marking. For herring, therefore, other methods must be introduced, and there seems to be no other way of working than to replace as far as possible observations of the single specimen at various ages by observations of a large number of specimens of different ages. A method of this kind was used by LEA (1910) and MOLANDER (1918). We shall refer below to another method which is based on the very same idea.

LEA (1910) measured the length (y) of a number of herring and a certain linear dimension (x) of a certain scale, calculated the ratio y/x for each single individual and arranged the material in age-groups. Apart from the mean ratio of the youngest age-group (1 year) no increasing or decreasing tendency of the mean can be observed (Table 6). It cannot be proved,

Table 6. Mean values of the ratio y/x for some age-groups. N stands for the number of individuals examined. From LEA (1910).

Age in years	y/x	N
1	29.7	74
2	29.0	36
3	27.1	2
4	27.4	11
5	28.7	33
6	28.3	218
7	28.5	19
8	28.4	2
9	27.9	3
10	28.6	6
11	27.9	7
12	28.3	1

however, whether the mean ratio of the youngest age-group deviates essentially from the means of the other groups. Attention must be called to the fact that the material, viz. the number of individuals examined, is rather small, a fact which causes the mean to be subject to great statistical errors. If, after all, we consider that the difference between the mean ratio of the group which contains the 1-year-old fish, and, for instance, the mean ratio of the group which contains the 6-year-old fish, is of essential significance, there is no reason to take this as a proof that the relation between the growth of the herring and that of its scales is not proportional. As will be proved below, the stock of Norwegian spring-herring, from which LEA has derived his material, is not a homogeneous body, but one consisting of two or three essentially different growth-types. It seems, therefore, obvious to suppose that the difference obtained is due to the fact that the composition of the different age-groups, examined by LEA, exhibits in different ratios of these growth-types. At the time when LEA undertook his investigation, it had not been observed that the stock of Norwegian spring-herring might be, or was, composed of different growth-types. If a new investigation is made along these lines in which attention is called to one growth-type only, more satisfactory results will presumably be obtained. It may, however, be taken for granted that this investigation by LEA points towards the supposition that the hypothesis in question is correct. LEA himself considered his investigation only as a preliminary study of the problem.

The very same method was used by MOLANDER (1918). He arrived at the conclusion that the relation between the growth of herring and that of its scales is not proportional. Attention must, however, be called to the fact that MOLANDER'S material is very small. Moreover, the above mentioned objections may obviously be argued against this conclusion, viz. that an essential difference — if such one can be proved — between the mean ratio (y/x) of two age-groups need not be due to the fact that the relation between the growth of herring and that of its scales is not proportional.

If there is any proportional relation between the growth of fish and that of its scales, this may — as stated above — be expressed by the equation:

$$f(t) = k \cdot p(t)$$

in which t denotes the age, $f(t)$ the growth-function of the fish and $p(t)$ the growth-function of the linear scale-dimension. The problem in question is, accordingly, reduced to the verification of this equation in an empirical way. This would be a simple matter if a single fish could be examined at every age, say at 1, 2, 3, ... n years of age. Let us suppose that this is possible, and moreover that it is possible at each of these ages to calculate by means of the scales according to the formula of proportionality, viz. according to the hypothesis that the fish and its scales grow in a proportional ratio, the length of this fish at the ages of 1, 2, 3, ... v years. These lengths are usually indicated by l_1, l_2, l_3, ... l_v. In the following discussion ${}_nl_v$ denotes the calculated length of the fish at the age of v years, the examination and calculation having been made at the age of n years. Thus ${}_5l_1$ denotes the calculated length at one year of age of a 5-year-old fish. Providing that there is a proportional relation between the growth of the fish and that of its scales, the values of the different l, l_1 for instance, must be independent of the age at which the fish is examined. If the hypothesis is in accordance with the real facts, the following equations must be correct:

$$
\begin{aligned}
{}_1l_1 &= {}_2l_1 = {}_3l_1 = {}_4l_1 = {}_5l_1 = \ldots. \text{ etc.}\\
{}_2l_2 &= {}_3l_2 = {}_4l_2 = {}_5l_2 = {}_6l_2 = \ldots. \text{ etc.}\\
{}_3l_3 &= {}_4l_3 = {}_5l_3 = {}_6l_3 = {}_7l_3 = \ldots. \text{ etc.}\\
&\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\
{}_vl_v &= {}_{v+1}l_v = {}_{v+2}l_v = {}_{v+3}l_v = {}_{v+4}l_v = \ldots. \text{ etc.}
\end{aligned}
$$

Provided the correctness of these equations can be proved, it can be taken for granted that there is a proportional relation between the growth of the fish and that of its scales[1]).

It is obvious that there can be no opportunity of examining the very same fish at various ages in the way described above. We must, therefore, try to collect statistical data which can compensate for the absence of data obtained by the examination of the same fish at different ages. For obvious reasons one ought to examine the very same year-class at different ages. Here, however, one is confronted by many difficulties. As has been mentioned above, the stock of Norwegian spring-herring, for instance, is not a homogeneous body, but is composed of two or three essentially different growth-types. If, therefore, we will use Norwegian herring data for the purpose of verifying the equations, a separation of the material into growth-types must be made, and the study must moreover be limited to one of these growth-types only.

In chapter III it will be shown that the individuals of a Norwegian herring sample can be separated into three groups according to the type of the growth. The following discussion deals only with the growth-type A which is characterized by decreasing yearly increments in length with increasing age.

Table 7. Mean values of l_1, l_2, etc. for the growth-type A of the year-class 1904 as large herring taken off the west coast of Norway.

Year	l_1	l_2	l_3	l_4	l_5	l_6
1909.....	8.6	16.6	22.4	25.7	27.7	29.2
1915.....	8.8	16.2	21.9	25.4	27.7	29.2

[1]) Dahl (1911), Sund (1911) and Hodgson (1925) have used similar methods and showed that calculated lengths agreed well with empirical ones. Lee (1912) does not take heterogeneity of the material into consideration.

In the first instance we will investigate the year-class 1904 as large-herring. Two samples only are at our disposal, one from 1909 and another from 1915. Table 7 shows the mean values of l_1, l_2, ... and l_6. It will be noticed that there are small differences between the mean values in the two samples. But these differences are too small to justify the conclusion that they are due to essentially different conditions. In this case the mean of l_6 is based upon actual observations in the 1909-sample and upon calculations in the 1915-sample. The mean values of this quantity are equal in both samples. As regards the other quantities (l_1—l_5) the means are based upon calculations for both samples. Here we have examined two samples only, and a more extensive material is obviously desirable.

Table 8 gives the mean values of l_1, l_2, l_3 etc. of the year-class 1904 as spring-herring. It will be seen that some of the samples have been collected in the very same year. The age of the herring was 5 years in the spring 1909 and 12 years in the spring 1916. The table shows that there are differences between the mean values of the quantities when the various samples are compared. Thus, the calculations show greater mean values for the individuals caught in 1911 (sample 24) than for those caught in 1912 (sample 27). But it will also be noticed that there are just as great differences when samples from the very same year are compared as there are when comparing samples from different years. If we compare sample 24, on the one hand, with sample 25, 26 and 27 on the other, it will be seen that the mean length of the individuals in sample 24 is greater than the mean length of the one year older individuals in sample 27, and equal to the mean length of the one year older individuals in sample 25 and 26. Accordingly we cannot expect to find that the mean growth in sample 27 is equal to that in sample 24. The growth differences in this case, seem to indicate that the hypothesis in question, which forms the basis of our calculations, is in accordance with the real facts. Of great interest is, however, the circumstance that the table does not show that the variation of the mean growth from year to year has any tendency. If the basis of the

Table 8. Mean values of l_1, l_2, etc. for the A-type of the year-class 1904 as spring-herring, taken at the west coast of Norway. N stands for the number of individuals examined.

Year	Sample No.	N	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}
1909.....	22	89	9.4	17.3	23.3	26.8	29.2							
	23	43	9.1	17.0	23.2	26.7	29.1							
1911.....	24	110	9.5	17.4	23.4	27.0	29.3	30.6	31.5					
1912.....	25	59	8.9	16.3	22.3	26.5	28.3	29.7	30.7	31.5				
	26	49	9.2	16.8	22.7	26.3	28.5	29.8	30.7	31.6				
	27	65	8.7	15.9	21.8	25.5	28.0	29.4	30.3	31.0				
1914.....	28	42	9.2	16.9	23.0	26.5	28.6	29.8	30.8	31.5	32.3	32.8		
	29	41	8.7	16.1	22.3	25.8	28.1	29.4	30.4	31.1	31.9	32.3		
	30	80	8.8	16.2	22.1	25.7	27.9	29.3	30.3	31.1	31.9	32.4		
1915.....	31	78	8.8	16.2	22.1	25.7	28.0	29.3	30.2	31.0	31.8	32.3	32.9	
	32	77	9.0	16.4	22.2	25.8	28.0	29.3	30.3	31.1	31.9	32.1	32.9	
1916.....	33	142	9.5	16.7	22.4	25.7	27.7	28.8	29.7	30.4	31.1	31.7	32.2	32.6

Table 9. Mean values of t_1, t_2, etc. for the A-type of the year-class 1904 as spring-herring, taken at the west coast of Norway. N stands for the number of individuals examined.

Year	Sample No.	N	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}
1909	22	89	9.4	7.9	6.0	3.5	2.4							
	23	43	9.1	7.9	6.2	3.5	2.4							
1911	24	110	9.5	7.9	6.0	3.6	2.3	1.3	0.9					
1912	25	59	8.9	7.4	6.0	4.2	1.8	1.4	1.0	0.9				
	26	49	9.2	7.6	5.9	3.6	2.2	1.3	0.9	0.9				
	27	65	8.7	7.2	5.9	3.7	2.5	1.4	0.9	0.7				
1914	28	42	9.2	7.7	6.1	3.5	2.1	1.2	1.0	0.7	0.8	0.5		
	29	41	8.7	7.4	6.2	3.5	2.3	1.3	1.0	0.7	0.8	0.4		
	30	80	8.8	7.4	5.9	3.6	2.2	1.4	1.0	0.8	0.8	0.5		
1915	31	78	8.8	7.4	5.9	3.6	2.3	1.3	0.9	0.8	0.8	0.5	0.6	
	32	77	9.0	7.4	5.8	3.6	2.2	1.3	1.0	0.7	0.8	0.5	0.5	
1916	33	142	9.5	7.2	5.7	3.3	2.0	1.1	0.9	0.7	0.7	0.6	0.5	0.4

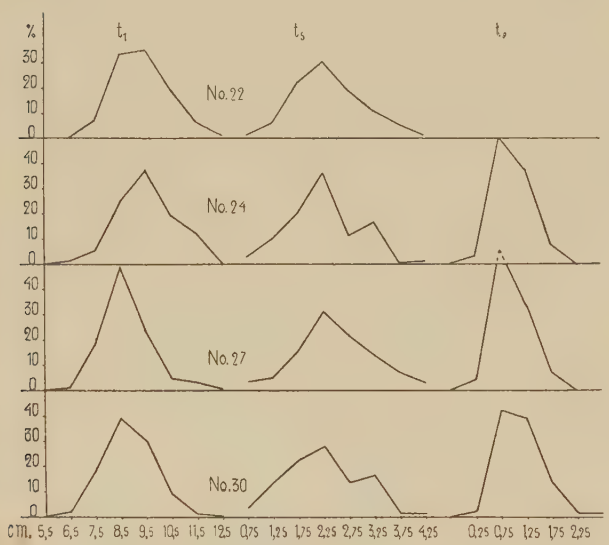

Fig. 2. Frequency curves for t_1, t_5 and t_7 for the A-type of the year-class 1904 as spring-herring in some samples.

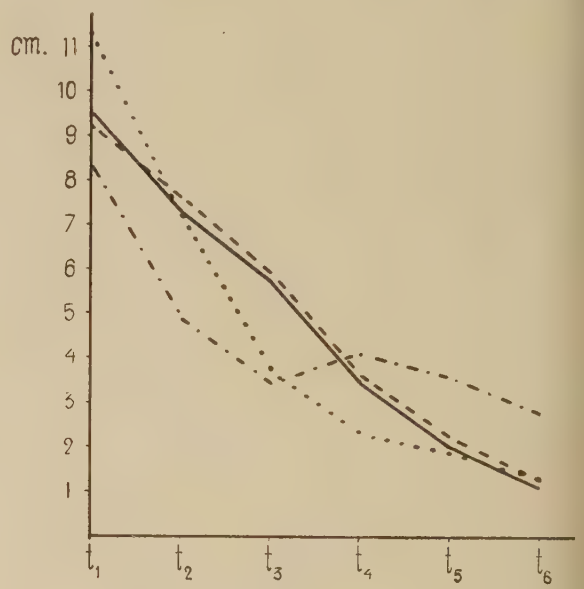

Fig. 3. Graphic representation of the mean yearly increments in length. ———— A-type of year-class 1904 in sample No. 33. — — — — — — A-type of the year-class 1904 in sample No. 26. —·—·—·— C-type of the year-class 1904 in sample No. 33. . . . . Year-class 1904 from Cornwall.

calculations upon which the table is founded does not agree with the real facts, this would necessarily be manifested in an increasing or decreasing tendency of the means. In this connection, however, a close study of the growth-differences, which endeavours to find the causes to which the differences are due, is of the greatest interest.

For obvious reasons, the yearly increments are better indicators of the growth than the quantities considered above. The mean yearly increments in length are given in Table 9 for the same samples as used in Table 8. It will be seen from this table that the growth-differences are applied only to the earliest years of life. From the third year upwards the growth-differences are very small. If we consider moreover the life-history of the herring, the differences in the first and second year are easy to understand. The Norwegian herring spawns in the coastal waters and in these waters the young herrings spend the first years of life. At an age of two or three years they migrate into the ocean. Evidently, the coastal waters afford varying environmental conditions for the growth, while the open sea is more uniform within larger areas. This agrees well with the facts illustrated by Table 9, viz. as regards the first and second year there are differences in the growth, while from the third year upwards the differences are very small. The differences in the first year, however, are not at all great. Comparing samples 24 and 30, we find a difference of 0.7 cm. which measured with its standard deviation is equal to 4.5. No proof can thus be given that this difference may not be eliminated or reversed if new data are collected. Considering the small number of individuals examined, obviously, no positive conclusion can be drawn. If we regard this

difference as a significant one, it may — as stated above — be understood in a very simple way, namely as caused by the variable environmental conditions present in the coastal waters.

In addition to the study of the variation of the means it is, however, desirable and necessary to study the distribution of the units according to the values of l_1, l_2, l_3 etc. or t_1, t_2, t_3 etc. We will confine ourselves with the investigation of only a few samples (22, 24, 27 and 30) and the quantities t_1, t_5 and t_7. As the number of individuals is small, the comparison between the different samples is best made by means of graphical illustrations. It will be seen from Fig. 2 that the very same values of the quantities are represented in all samples. Thus for t_1 we find the values from 6.5 to 12.5 cm., for t_5 the values from 3.75 cm. to 4.25 cm. and for t_7 the values from 0.25 cm. to 2.25 cm. Apart from a few exceptions this applies to all samples. As regards t_5 and t_7 we find, moreover, that the frequency curves have their maxima for the very same value. This does not apply to t_1, a fact which agrees well with the variation of the means and which — as argued above — is not due to any causes of importance. The calculations by means of the proportional formula not only give the same mean values of the yearly increments in length at different ages, but also the same frequency distributions.

As a result of these investigations we must take it for proved that the hypothesis in question agrees well with the real facts. At all events the hypothesis is so approximately correct that the calculations give reliable and comparable values. If we enter in a diagram the curves for the increments in length for two of the samples in Table 9, it will be seen (Fig. 3) that the two curves are approximately identical. For the purpose of comparison we have also drawn the corresponding curve for the year-class 1904 from English waters (data from Hjort and Lea 1910, coll. 28, p. 160) and the curve for another growth-type (C) of the year-class 1904 as Norwegian spring-herring. It must be admitted that we are here confronted with three essentially different growth-types. For the samples considered the growth differs to such an extent that it entitles us to take this diagram as evidence of fundamental and characteristic differences between the environments in which the three groups of herring have spent their life.

CHAPTER III

On the growth of the herring in different environments.

Even the first investigations of the Norwegian herring showed that different growth-types exist (Dahl 1907, Broch 1908), and later on international research has thrown more light upon this matter. It has been demonstrated that the various areas of the sea are inhabited by different growth-types of herring and, particularly, that herring from the ocean grow faster than herring from closed waters. The problems which arise from these observations have been subject to further investigations, and it has been discussed in particular whether the growth-rate can serve as indication of herring migrations. In this connection some investigations by Storrow (1924, 1932) are of great interest. The herring generally spends its first years of life in coastal waters. At any rate this applies to the Norwegian herring. Storrow argues now that the migration from the coastal waters to the open sea cannot take place without giving the growth of the migrated herrings a certain character. Lea (1911) found that the growth of some herrings is characterized by a larger increment in the 4th than in the 3rd year, and Storrow is of the opinion that such growth-mark is caused by migration. We shall revert to this matter later on.

Within the Norwegian herring population different growth-types are to be found. Thus Fig. 4 shows that herring caught in southern Norwegian coastal waters grow faster than those caught in northern waters.

Lea (1911) has proved that the growth of the herring in the coastal waters of southern Norway takes place in the months from April to September, while the growth stagnates between October and March. The optimum growth-rate occurs in May—June. In order to prove whether there is any difference between the seasonal growth in the coastal waters of southern and northern Norway, samples of small herring were collected in the summer of 1933 in a southern and a northern area. In this way an idea of the seasonal growth of the year-class 1932 (herring in 2nd year) was obtained. The southern area includes fishing grounds from south of Bergen to Møre and the northern area fishing grounds near Tromsø. Fig. 5 gives an illustration of the growth. As regards the southern area the growth curve has a somewhat irregular course, a result which in this case may be expected as the samples have not been collected in the same locality. The points which represent the observations in the figure lie, however, approximately on a smoothed curve with a regular course. The growth curve for the northern area is based on a rather small number of observations. But, undoubtedly the curve gives a good picture of the growth.

The diagram shows that there is an essential difference between the seasonal growth in the two areas. In the first place, it will be noticed that the growth in the southern area has continued during

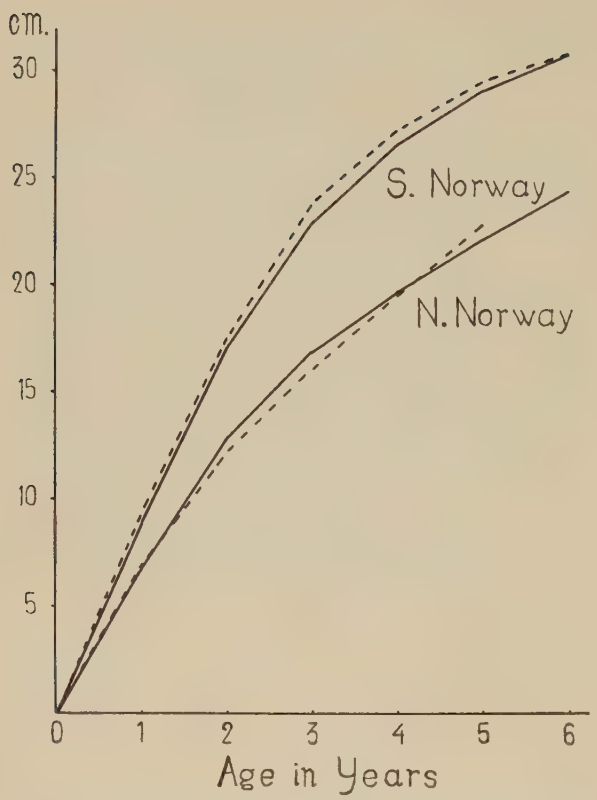

Fig. 4. Growth curves for Norwegian herring from southern and northern Norway. ———— Year-class 1902, — — — — Year-class 1904.

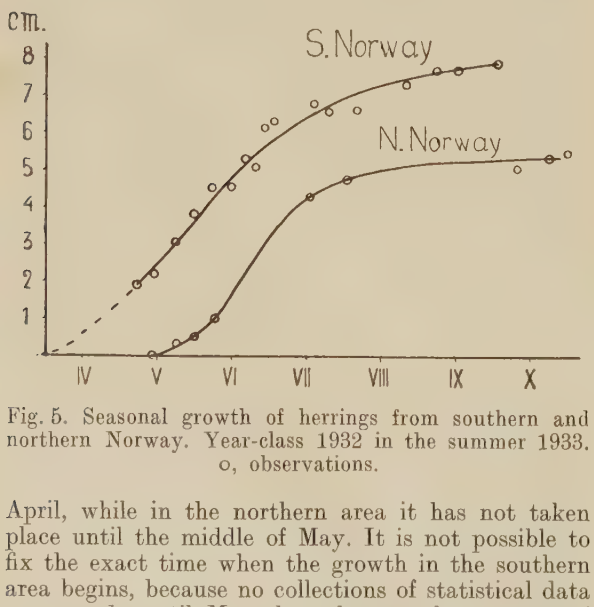

Fig. 5. Seasonal growth of herrings from southern and northern Norway. Year-class 1932 in the summer 1933. o, observations.

April, while in the northern area it has not taken place until the middle of May. It is not possible to fix the exact time when the growth in the southern area begins, because no collections of statistical data were made until May, but the complete course of the growth indicates that it takes place as early as the first days of April. It will be seen, moreover, that the growth continues during September and probably during October also. This agrees well with the results of Lea's investigation (1911). In the northern area, on the other hand, the growth seems to have ceased as early as the latter half of August. Indeed, no observations during a long period are at our disposal, and we are reduced to drawing our conclusions from the general impression which the growth-curve gives.

According to the statements given above the duration of the growth-season is about 7 months in the southern area (from the beginning of April to the end of October) and about $3^1/_2$ months in the northern area (from the middle of May to the end of August). Finally, we observe that the total growth in the southern area is about 8 cm. while in the northern area it is only about 5.3 cm.

The cause of this growth difference must be sought in the temperature. Fig. 6 illustrates the variation in

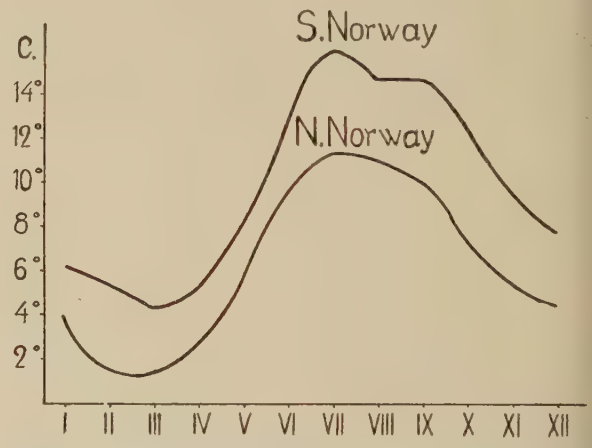

Fig. 6. Sea-surface temperature in southern (Hellisøy) and northern (Andenes) Norway.

the surface temperature from month to month at a southern and a northern locality (Hellisø and Andenes)[1]). It will be observed that the very same periodical variation is found at both localities. The temperature at the southern locality, however, is considerably higher than that at the northern. In this connection not the surface temperature but that in the depths is the deciding factor. As a rule the latter follows the surface temperature although the maximum occurs somewhat later than at the surface.

There is a correspondence between the temperature variation and the growth of the herring which is probably not accidental. We have previously seen that the growth in the southern area takes place at the beginning of April and in the northern area at about the middle of May. The surface temperature at the southern locality is about 4.7° C. at the beginning of April, while at the northern locality it is about 5° C. in the middle of May. Moreover, we have

[1]) Data received from Meteorologiske Institutt, Oslo.

seen that the growth ceases in the southern area at the end of October and in the northern area in the last half of August. The surface temperatures at corresponding times are 11° C. and 10.6° C. Thus the growth starts at the same temperature in the two areas and ceases at the same temperature. Whether there is any correlation between these two events cannot be proved with our present experience. We have mentioned this fact here in order to call attention to the coincidence.

As already mentioned it has been proved that different waters are inhabited by different growth-types of herring. Moreover, it has been demonstrated that there are different growth-types within the Norwegian herring population. There is thus an essential difference between the growth of the herring which is caught as spring-herring in southern Norway and that of the herring which is caught as fat-herring in northern Norway. The question has therefore been raised, whether it is possible by means of growth studies to characterize the herring of the different localities and thereby create a method for the study of the ever-present problem of the distribution of the herring, its migrations and other questions associated with these. This problem has been discussed in many papers (Hjort, Lea, Storrow, Ford a. o.).

The following investigation will prove that there are, as a rule, two or three growth-types in every Norwegian herring sample. The task is to try to seperate these growth-types. This is possible if any qualitative signs are found by means of which the sub-division can be carried into effect. Concerning these questions nothing can be argued in general, as the method of attacking the problem depends upon the kind of material available and other circumstances. The close study of the growth of the herring will as a rule furnish a statistical analysis of material containing tables of l_1, l_2, l_3 etc. for each single individual and, in addition to these, such characters as sex, stage of sexual maturity etc., and this material must be utilized as completely as possible. If our object, however, is to study the migrations, some rules for the investigation may be indicated. The most important thing is to fix the area from which the herring originate. Some hints regarding this matter may be obtained by examining the growth in the first two years of life. This, however, is not sufficient. To solve this problem, information regarding other facts — hydrographical and biological — are needed. If the solution of this problem is possible, the study of the growth in the following years may give us some hints regarding the areas of the sea within which the herring have migrated. Here, however, the investigator is also confronted with many difficulties, for instance the fact that there is a certain correlation between the increment in a certain year of life and the growth in the earlier years. This difficulty and others must be surmounted in every single case. It is not possible to indicate general rules for treating such problems as those considered here.

The "marking" phenomenon.

When we consider each single individual in a herring sample, it is found that the growth of some of these is characterized by decreasing yearly increments ($t_1 > t_2 > t_3 >$ etc.) with increasing age, while the growth of others is characterized by larger increments in the 3rd year than in the 2nd ($t_2 < t_3$) or by larger increments in the 4th year than in 3rd ($t_3 < t_4$) while in addition the other yearly increments decrease with increasing age. Lea (1911) was the first investigator who observed herring whose growth is characterized by larger increment in the 4th than in the 3rd year. At that time, Lea was of the opinion that this growth was abnormal and assumed that the abnormality ($t_3 < t_4$) was due to the fact that the said individuals had spent their 3rd year of life in waters which present unfavourable environmental conditions for the growth. This opinion was the most likely one as, at that time, the said individuals were known only within a certain year-class (1904) and only within the Norwegian herring population. Later on, however, such "marked" herring — as they were called by Lea — have been observed in other waters and within different year-classes. Storrow (1924) who described the appearance of such herring in English waters is of the opinion that the "marking" phenomenon is due to migrations from for growth less favourable to more favourable waters and, particularly, to the migration from coastal waters to the open sea. The growth conditions in the open sea are, as a rule, more favourable than those in coastal waters.

As regards the Norwegian herring the appearance of "marked" individuals is a common feature for all year-classes. In addition to those described by Lea we usually find individuals the growth of which is characterized by larger increment in the 3rd year than in the second ($t_2 < t_3$). Accordingly, three growth-types appear and Fig. 7 gives a schematic picture of a scale from each of these growth-types. In scale A the width of the summer zone decreases from the centre towards the edge, in scale B the width of the 3rd summer zone is larger than that of the second, and in scale C the width of the 4th summer zone is larger than that of the 3rd. In addition to these growth-types there appear in some herring samples individuals whose growth is characterized by lesser increment in the first year than in the second. These individuals appear in such small numbers that this growth-type will not be taken into consideration in the following discussion.

Table 10. Percentage composition of the stock of fat-herring in growth-types.

Year-class	Year	Growth-type A	B	C
1904.....	1909	15.6	5.3	79.1
1913.....	1915	74.5	25.5	—
1921.....	1924	26.6	16.9	56.5

Table 10 presents the percentage number of individuals of the three growth-types for some year-

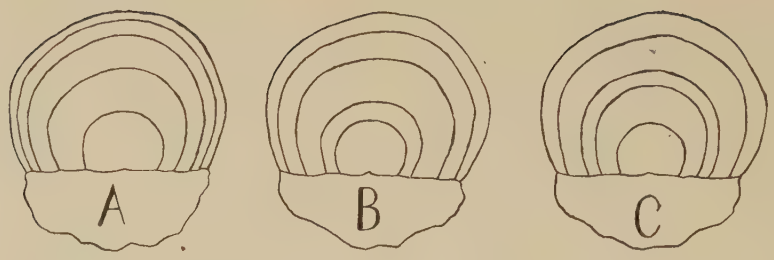

Fig. 7. Scales from herrings of the growth-types A, B and C. See text.

Table 11. Percentage composition of the stock of spring-herring in growth-types.

Year-class	Year	Growth-type A	B	C
1904.....	1911	53.7	13.1	33.2
1904.....	1916	45.8	12.9	41.3
1910.....	1916	40.7	15.3	44.0
1918.....	1925	43.5	35.0	21.5

classes in fat-herring samples. Table 11 presents the same fact for the spring-herring. From these tables it will be observed that a considerable portion of the stock appear as growth-types B and C. In the following chapters similar data will be described in regard to other year-classes. We have only given these tables here for the purpose of showing that the growth-types B and C are common in the herring samples.

Methodically, an investigation of the growth of the herring must commence with the sub-division of the samples. Separation of age-groups (year-classes) ought to come first. In the next place sub-division according to sex may be considered. Our investigations along this line have proved, however, that the two sexes grow at the same rate. As the growth-types A, B and C appear in the very same samples, it is necessary to separate these as well. Mention may be made of an example of subdivision of this kind. Fig. 8 gives an illustration of the frequency distribution for the 3rd increment in growth (t_3) for the year-class 1904 in a sample of large herring from 1915. It will be seen that the frequency curve for the total sample of the year-class 1904 shows two distinct maxima. The separation of the growth-types A and C results in two nearly symmetrical and well-defined frequency curves for these growth-types. In the sample some individuals of the growth-type B also appeared, but the number is very small and there is thus no reason to take this growth-type into consideration in this connection. The reason for choosing this sample is the fact that it indicates a source of error which must be taken into consideration. It will be observed that some of the individuals which belong to the C-type have larger growth increments in the 3rd year than the others. This applies to the individuals having the increments 6.5 cm. and 7.5 cm. These individuals certainly belong to the biological group of herring which is represented by the A-type. In the example here considered this fact is especially obvious.

The following analysis of the Norwegian stock of herring is based upon this sub-division of the samples. It will be shown that, whatever sample is considered, the growth-types B and C have lesser increments in length in the first two years of life than the A-type. This must be taken as an evidence that the A-type originates in different and, for growth, more favourable waters than the growth-types B and C. As

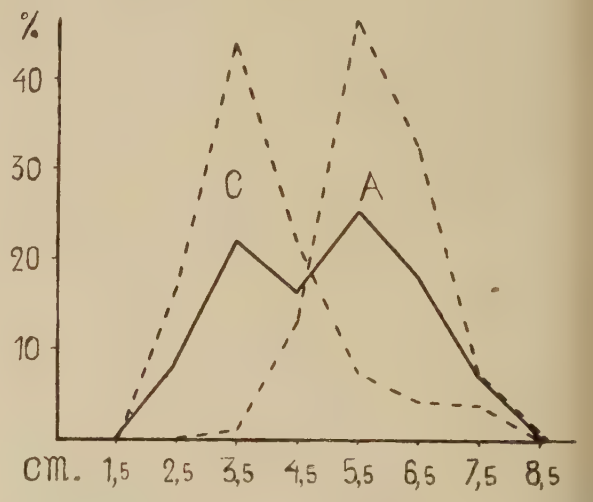

Fig. 8. Frequency curves for t_3 of the year-class 1904 as large-herring in 1915. ———— total sample, — — — — growth-types A and C.

southern coastal waters induce a more rapid rate of growth than northern waters, we may clearly take it for granted that the A-type derives from more southern waters than the two other growth-types. If, therefore, the three growth-types are represented in the same sample of herring, our sub-division according to the signs which separate the growth-types affords a means of separating two or three groups of herring whose life history is different. In this way we get a basis for the study of the fundamental problem of herring migrations.

CHAPTER IV.

The stock of Norwegian fat-herring.

About 65 years ago SARS and BOECK argued that the fat-herring in the Norwegian coastal waters represents the juvenile stage in the life history of the Norwegian herring. Later investigations have verified this opinion. The fat-herring are young fish with very small sexual organs and it is only by the largest individuals that sexual development may be observed. The fat-layer in the flesh and at the intestines is on the other hand strongly developed and is larger than by any other kind of herring.

The fat-herring is the object of fishing along the entire coast of Norway, but the quantities caught are very different in the different areas. According to "Norges Fiskerier" Table 12 gives the total

Table 12. Quantity of fat-herring landed in Norway. (1000 Hl.)

Fylke (district)	Year			
	1928	1929	1930	1931
Rogaland	900	4,650	2,500	3,500
Hordaland	13,966	6,650	400	3,820
Sogn og Fjordane	5,460	1,049	1,550	850
Møre	25,187	12,845	27,281	11,452
S.-Trøndelag ..	34,995	149,166	134,939	30,190
N.-Trøndelag ..	14,045	2,360	55,990	6,698
Nordland	178,956	30,656	29,245	39,598
Troms	971,433	625,717	146,795	13,533
Finmark	—	755	13,047	11,400
Total...	1,244,942	833,848	411,747	121,041

quantities caught in various districts (Fylke) from the southern west coast to Finmark during four consecutive years. It will be seen that the largest quantity has been fished in Troms. Moreover, it will be noticed that the quantity varies strongly from year to year as well when comparing each district separately as when comparing the districts together. These fluctuations in the yield of fisheries which apply to nearly all salt-water fisheries, have been explained through proving that the number of individuals of the different year-classes varies to a great extent (HJORT 1914). As regards the fat-herring fisheries in the Norwegian coastal waters, other factors may also play a certain part, a fact to which we will revert later on.

The age-distribution of fat-herring samples also varies considerably. In some years fat-herrings of $5^1/_2$ years of age were caught, while in other years, 1915 for example, the oldest individuals were only $3^1/_2$ years of age. This fact too was probably caused by the different number of individuals of the year-classes. Thus, the $5^1/_2$ year old herring in the samples from 1909 belong to the extraordinarily numerous year-class 1904.

It is obvious that these fluctuations both in quantity and in quality soon became the object of attention. The very question as to the causes of these fluctuations in quantity, has been answered through the discovery that the number of individuals of the various year-classes differs to a very great extent. But many questions are still left open. As regards the Norwegian fat-herring the question is, particularly, what factors cause the variation of the appearance of the shoals. One year the fat-herring fisheries are a success in some coastal districts and a failure in others. The next year the fact may be just the opposite. LEA (1929, 2) has discussed these matters. He is of the opinion that the causes of these variations are that the stock of fat-herring is composed of two contingents, i. e. coastal herring and what he calls oceanic herring. When large yields of fat-herring are caught in a certain district, this is due to the fact that the oceanic fat-herring on their migrations in the sea happen to approach this coastal district. In a district where this immigration of oceanic herring is a failure, the fishery results in small quantities of small coastal herring. "It looks more as if the so-called "large fat herring years" occur when the oceanic group of herring, or portions of them, are driven to the coast as a consequence of circumstances, which at the present moment are unknown, or when the departure from the coast in order to take up an oceanic existence is, so to speak, delayed."

The present investigation of the age and growth of the fat-herring does not intend to give a complete solution of all these problems. For this purpose the material at hand, is not sufficient, and we can only show what is happening in some single years. The facts which are presented here, however, induce a certain interpretation, and we are first going to give a survey of the results.

The most striking feature is that the fat-herring stock, considered as an entire body, is composed in a very complicated way. It almost seems that the coastal waters of northern Norway in the autumn months are the meeting place of some contingents or groups of the Norwegian herring population.

When we consider the problem, raised by LEA, of the immigration of oceanic herring to the fat-herring shoals, a very illustrating example of this migration is found in our material. In most samples from the autumn of 1915 it can be observed that the stock upon which the fishery at the beginning of the season is based, is enlarged by large, fast-growing fat-herring. There is no doubt that this is due to an immigration which originates in the ocean, and moreover that these immigrating herring represent the oceanic stage referred to by LEA. The stock of oceanic herring seems to be uniform as well in regard to age-distribution as in regard to size. For the yield of fat-herring fishery in the districts where this immigration took place, the oceanic herring undoubtedly played a dominating part.

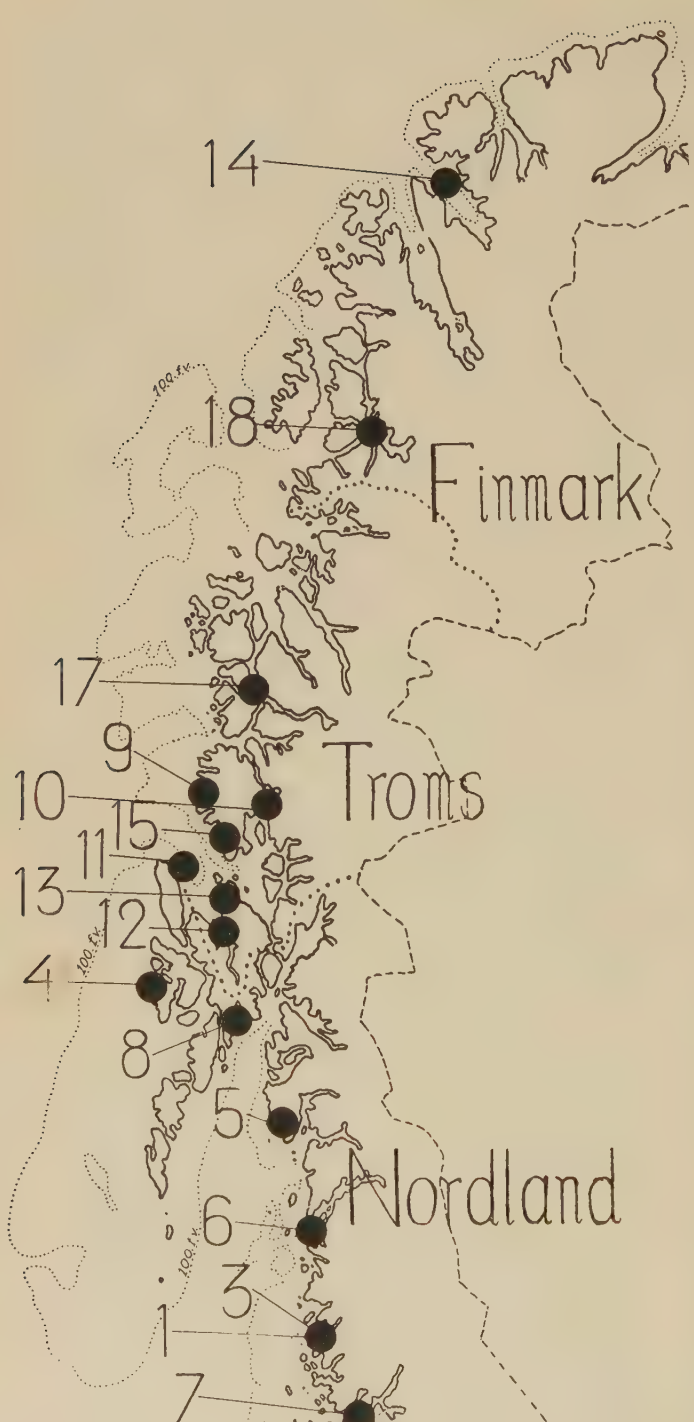

Fig. 9. Localities where the different samples of fat-herring are collected.

In a sample from the autumn of 1920 we find moreover some facts which seem to indicate a said immigration of oceanic herring. In this sample two groups of the A-type are, undoubtedly, represented one of which has faster growth than the other. It cannot be accepted that the group which has the faster growth, is coastal herring. However, several circumstances indicate that we are in this case confronted with other facts than in 1915. Thus a sample from Petsamo proves that herring with very large growth-rate are also found in more northern waters. The immigration to the coastal waters in 1920 originates very likely in these waters. As the present material is rather small, we cannot assert that this hypothesis is correct. But we will call attention to this coincidence as a possibility, worthy of a closer investigation.

The Norwegian fat-herring stock is not, however, complex only in the sense that it is composed of oceanic herring and coastal herring. It appears also that the coastal contingent is composed of several groups i. e. the growth-types mentioned above and defined as A, B and C. It will be proved that these growth types have different growth-rate. The length increments in the first and the second year of life are greater for the A-type than for the other types. The difference, however, is very small when compared with the difference which appears between the growth of the coastal herring on the one hand and the oceanic herring on the other.

The reason why we have used the term "oceanic herring" for the one contingent of the fat-herring cannot be explained here because it requires statements regarding the growth of the large-herring and the spring-herring, a matter to which we shall revert later on. Our analysis, however, has led us to the view that the oceanic herring originate in the coastal waters of southern Norway. In these waters they spend their first and second year of life, and in the third year they migrate to the ocean. In some years they happen to approach the coast of northern Norway. The coastal fat-herring, on the other hand, have spent their life in the coastal waters of northern Norway.

The problem now arises how to explain the fact that "marked" herrings (growth-type B and C) are found among the coastal herring. We have mentioned above the explanation of this marking phenomenon given by Storrow. He argues that a herring becomes marked when it migrates from the coastal waters to the open sea. Attention must be called to the fact moreover, that a herring must become marked when it migrates from a less favourable to a more favourable area of the sea if the two areas present essentially different growth conditions. In the case of insignificant difference, the migration may take place without making any mark in the growth. When we consider the extensive tract of coast, which comes in question in regard to the Norwegian fat-herring, it is obvious that the waters where the coastal herring spend their life, present highly varying growth con-

ditions. When this fact is taken into consideration, the existence of the two marked growth-types (B and C) as caused by migrations within the coastal waters is not so strange.

Certainly, it is not correct to take the coastal herring as stationary. It may be that a group of herring is staying in a closed fiord during shorter or longer time. However, we must take it for granted that the coastal herring as a rule migrate, a fact which the occurrence of marked herring seems to prove. But the migrations must be supposed to be limited to the coastal waters.

We have mentioned above the main results from our investigations of the age and growth of the fat-herring. We have given a short survey of them here in order that the following analysis, which indeed forms the basis of our conclusions, may be more easily understood.

The year-class 1904.

For the purpose of investigating the year-class 1904 as fat-herring five samples are at our disposal, two samples from the autumn of 1907, one from 1908 and two from 1909. The age-distribution of these samples is given in Table 13. The localities

Table 13. Percentage composition of the stock of fat-herring in year-classes.

Sample No.	Year	Date	Year-class 1907	1906	1905	1904	1903	1902	Total
1.....	1907	10/8	—	—	44.3	55.7	—	—	97
2.....	—	14/9	—	34.4	49.5	16.1	—	—	93
3.....	1908	13/8	—	32.0	10.0	58.0	—	—	100
4.....	1909	28/8	—	22.4	19.7	56.6	—	1.3	76
5.....	—	Aug.	4.3	34.8	12.5	46.2	2.1	0.2	610

where the samples have been collected, are plotted on the chart Fig. 9. We have previously called attention to the fact that the age-distribution of fat-herring samples can vary considerably. These samples are characterized by the representation of very old individuals.

Table 14. Percentage composition of the stock of the year-class 1904 in growth-types.

Sample No.	A	B	C	Total
1.....	42.6	16.7	40.7	54
3.....	25.9	6.9	67.2	58
5.....	15.6	5.3	79.1	282

Table 14 shows the percentage number of individuals of the different growth-types of the year-class 1904. It will be observed that during the time from the autumn of 1907 to the autumn of 1909 a change has taken place. The number of herring examined is — as will be seen — rather small, at all events in samples 1 and 3. But for all that the tendency points undoubtedly in the direction of decreasing percentage number of individuals of the A-type from 1907 to 1909. This seems also to apply to the B-type, while the percentage number of individuals of the C-type is, accordingly, increasing. This change may be explained either by herring of the A-type having migrated out of the fat-herring shoals from the autumn of 1907 to the autumn of 1908, and from that time to the autumn of 1909, or by an immigration of herring of the C-type to these shoals in the years 1908 and 1909. But of course, both these movements may have taken place.

The following investigation of the growth gives some hints for the correct answer to this question. As the B-type in our samples is represented by a rather small number of individuals, we will confine ourselves to the consideration of the two other growth-types (A and C). Table 15 shows the mean

Table 15. Mean (m) total length in cm. of the individuals of the year-class 1904. N stands for the number of fish examined.

Sample No.	A		C	
	m	N	m	N
1.....	22.8	23	21.4	22
3.....	24.7	15	24.0	39
5.....	26.6	44	25.7	223

length, and it will be seen that the mean for the growth-type A is in all samples greater than that for the growth-type C. As the material is rather small, the means are subject to great statistical errors. It will be seen, however, that the differences point in the same direction in all samples, and we may, accordingly, be allowed to draw the conclusion that the mean length for the A-type is essentially greater than that for the C-type.

The very same result will be obtained by the examination of the growth. Preliminary, we will limit the investigation to a comparison between the length increments in the first two years of life (t_1 and t_2). The comparison between the two growth-types (Table 16) proves that the mean both of t_1

Table 16. Mean values (in cm.) of t_1 and t_2 for the growth-types A and C of the year-class 1904 as fat-herring. N stands for the number of individuals examined.

Sample	A			C		
	t_1	t_2	N	t_1	t_2	N
1.....	7.3	6.3	23	7.1	5.4	22
3.....	7.4	6.1	15	7.0	5.0	39
5.....	7.3	6.0	44	6.8	4.9	223

and of t_2 is greater for the A-type than for the C-type. This applies to all samples. As regards t_2, the differences are great, lesser as regards t_1, and they point in the same direction in all samples. As it is of great interest to calculate a measuring figure for these differences, we have computed the standard deviation of the means, having taken all samples as a whole (Table 17). For t_1 we find the difference

Table 17. Mean values (m, in cm.) of t_1 and t_2 for the year-class 1904. μ stands for the standard deviation of the mean and N for the number of individuals examined.

Growth-type	t_1		t_2		N
	m	μ	m	μ	
A	7.3	0.111	6.1	0.158	82
C	6.9	0.043	4.9	0.054	284

0.4 cm. and for t_2 the difference 1.2 cm. Measured with their standard deviations these differences are equal to 3.4 and 7.2 respectively. As regards t_2, accordingly, the probability is very small that this difference would be eliminated or reversed if new observations were collected under the same conditions. Above we have seen that the differences point in the same direction as regards all samples both for t_1 and t_2, and there is thus no doubt that the causes determining the growth-rate in the first two years of life, have been essentially different for the two growth-types.

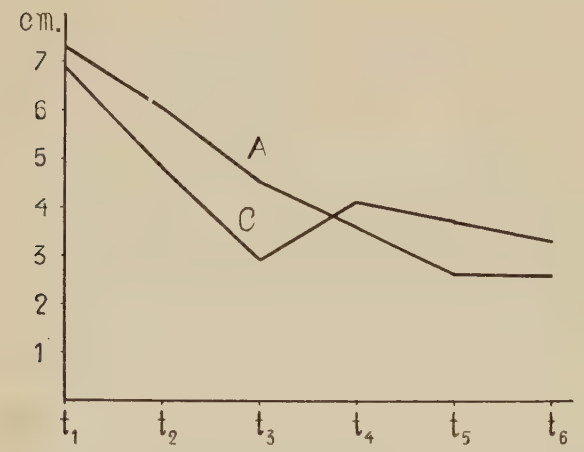

Fig. 10. Graphic representation of the mean yearly increments in length of the growth-types A and C, of the year-class 1904 as fat-herring from northern Norway.

Fig. 10 demonstrates that in all years of life the length increments have been different for the two growth-types. In the first three years the A-type has the greatest increments, from the 4th year and upwards, however, the C-type.

As regards other characters, the two growth-types are also different. Thus, if we examine the development of sexual organs by means of the table generally used (see HJORT 1914), we find that the C-type remains behind the A-type. Table 18 shows that 54.6 % of the individuals of the C-type stand at stage I and only 13.4 % at stage II. As regards the A-type only 29.5 % stand at stage I, while 27.2 % at stage II and 18.2 % at stage III. The divergence between the two growth-types does not, accordingly, consist in growth difference only, but also in the fact that the sexual organs of the A-type, as a group considered, are more developed than those of the C-type.

Table 18. Percentage composition of the stock of the year-class 1904 in groups according to the stage of sex. organs. Material sample No. 5.

Growth-type	Stage of sex. organs						
	I	I-II	II	II-III	III	III-IV	V
A	29.5	9.1	27.2	11.4	18.2	4.5	—
C	54.6	26.9	13.4	1.3	2.9	0.4	0.4

Above, we have discussed the change in the percentage number of individuals of the different growth-types from the autumn of 1907 to the autumn of 1909, and we have explained this change as due either to an immigration of herring of the C-type or to an emigration of herring of the A-type or to both these migrations. We have now seen that the A-type is represented by larger and faster growing individuals

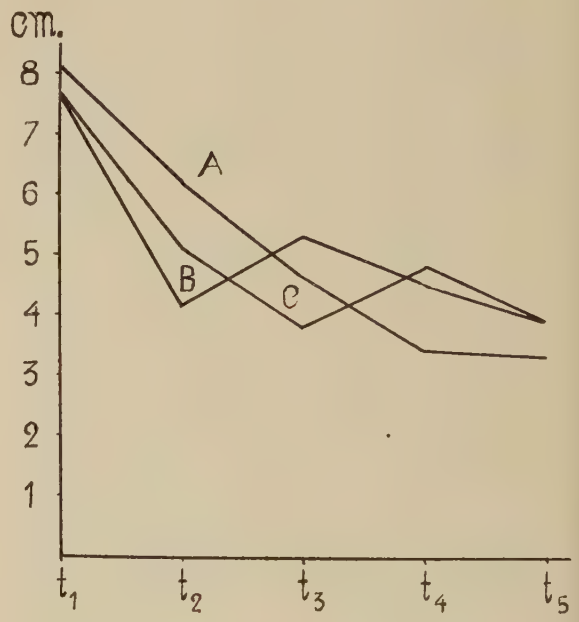

Fig. 11. Graphic representation of the mean yearly increments in length of the growth-types A, B and C. Year-class 1905 as fat-herring 1909.

than the C-type and, moreover, that the C-type is behind the A-type as regards the development of sexual organs. These facts besides the great age of the year-class indicate that the change is due to individuals of the A-type having migrated into the ocean in order to take up the oceanic existence.

Preliminary, however, our task must be limited to proving that the growth divergence, mentioned above, applies also to other year-classes. In the samples used, only one year-class (1905) is represented by such a large number of individuals that the growth can be examined with considerable accuracy, and we will now proceed to examine the growth of this.

The year-class 1905.

As a basis for the examination of the year-class 1905 we have at our disposal only the sample 5. Of the total number of individuals of the year-class 32.9 % belong to the A-type, 42.1 % to the B-type and 25 % to the C-type. As regards the growth, it will be seen from Table 19 that the length increment

Table 19. Mean values (in cm.) of t_1 and t_2 for the year-class 1905 as fat herring. N stands for the number of individuals examined.

Growth-type	t_1	t_2	N
A	8.1	6.2	25
B	7.7	4.2	32
C	7.7	5.1	19

both in the first and in the second year of life is greater for the A-type than for the two others. The growth-types B and C have the very same length increment in the first year, while in the second year the C-type has greater increment than the B-type. Moreover, it will be seen from Fig. 11 that the complete course of growth is essentially different for the three growth-types. The facts are just parallel to those for the year-class 1904.

The year-class 1907.

For the purpose of examining the year-class 1907, we have at our disposal a sample from the autumn of 1909 (sample 6) of which the year-class 1907 amounts to about 92 %. In the autumn of 1909 the age of this year-class was $2^1/_2$ years, but as the sample was not collected until the seasonal growth had ceased, t_3 was fully formed. Accordingly the growth-type B is represented. 35.6 % of the number of individuals of the year-class belonged to this type.

Table 20. Mean values in cm. (m) of t_1 and t_2 for the year-class 1907 as fat herring. μ stands for the standard deviation of the mean and N for the number of individuals examined.

Growth-type	t_1		t_2		N
	m	μ	m	μ	
A	7.8	0.034	6.7	0.031	753
B	7.2	0.038	5.7	0.033	416

In Table 20 the means of t_1 and t_2 for the A-type and the B-type are given. It will be seen that both of t_1 and of t_2 the means are greater for the A-type than for the B-type. As regards t_1 we find the difference 0.6 cm. which measured with its standard deviation is equal to 15.0, and as regards t_2 we find the difference 1.0 cm. which measured with its standard deviation is equal to 22.1. Accordingly, the probability is very small that these differences would be eliminated or reversed if new observations were collected under the same conditions. We thus observe that the very same facts also apply to the year-class 1907 which have been found for the year-class 1905, viz. that there is an essential difference in the growth between the A-type and the B-type. The length increments in the first two years of life, particularly, are greater for the first than for the latter growth-type.

The stock of fat-herring in the autum of 1915.

From the fat-herring shoals in the autumn of 1915 we have at our disposal a very comprehensive and interesting material. We have a total of 8 samples which have been collected in different localities and at different times. Table 21 shows the age-composition

Table 21. Percentage composition of the stock of fat-herring 1915 in year-classes.

Sample No.	Date	Year-class 1914	1913	1912	1911	Total
7.....	$^{28}/_{8}$, $^{30}/_{8}$ and $^{3}/_{9}$	45.2	53.8	1.0	—	591
8.....	$^{27}/_{10}$	71.5	27.5	1.0	—	284
9.....	$^{10}/_{9}$	89.0	11.0	—	—	254
10.....	$^{9}/_{10}$	54.8	44.0	1.2	—	241
11.....	$^{17}/_{10}$	—	70.7	29.3	—	157
12.....	$^{20}/_{10}$	13.7	59.5	25.2	1.6	190
13.....	$^{28}/_{10}$	36.3	55.5	8.3	—	265
14.....	$^{8}/_{10}$	13.9	84.7	1.4	—	281

of these samples. It will be observed that it is the year-classes 1914, 1913 and 1912 which are represented, and in addition to these in one sample (12) some individuals of the year-class 1911. The localities where the samples have been collected, are plotted on the chart Fig. 9.

The above investigation has proved that the fat-herring population is complex, in the sense that it is composed of the three growth-types A, B and C. The growth of these types is different, and particularly the A-type has greater length increments in the first two years of life than the two other types. Whether the growth-types B and C grow at different rate in the first and second year cannot be proved with our present material. These growth divergences indicate that the A-type originates in another spawning area than the growth-type B and C, and in that sense we may talk about — in any case — two contingents as composing the fat-herring stock. The following investigation shows that the stock of fat-herring is complex in another sense also. It will be proved that two essentially different groups both belong to the A-type. One of these groups belongs to the coastal herring and the other to the oceanic herring. Preliminary, we will confine ourselves to the examination of the year-class 1913.

It will be seen from Fig. 9 that five of the samples have been collected in nearly the same locality. These samples (9—13) we have numbered chronologically, and about 6 weeks have elapsed between the collection of the first and the last sample. In these samples the year-class 1913 is represented both by the A-type and by the B-type. Preliminary, we will deal with the first growth-type only, and Table 22 shows the age-distribution of this growth-type, viz. the age-distribution including only the A-type of all year-classes present. It will be observed that the year-class 1914 dominates in samples 9 and 10, though in such a way, however, that the percentage number of individuals of this year-class is larger in the first than

Table 22. Percentage composition of the stock of A-type in year-classes.

Sample No.	Year-class 1914	1913	1912
9	92.6	7.4	—
10	64.7	35.3	—
11	—	86.3	13.7
12	18.4	75.2	6.4
13	43.8	53.0	3.2

in the second sample. In sample 11 different facts appear. In this sample the year-class 1913 is the dominating one, and the year-class 1914 is not represented at all. In the last two samples (12 and 13) all the three year-classes (1914, 1913 and 1912) are represented, but it will be seen that the percentage number of individuals of the year-class 1914 is larger in sample 12 than in sample 13. We will once more mention that these samples are numbered chronologically, and thus it may be thought that the age-distribution of the last two samples (12 and 13) results through sample 11 having been mixed with herring of the year-class 1914. It is obvious that a sample which results of combining sample 9 and 11, will show an age-distribution like that of samples 12 and 13.

This very fact seems to indicate that there are in these waters two contingents of the fat-herring, and we shall in what follows show that other circumstances point in the same direction. First we will consider the ratio between the numbers of the individuals of the growth-types A and B of the year-class 1913. It will be seen from Table 23 that this ratio varies

Table 23. Percentage composition of the year-class 1913 in growth-types.

Sample No.	A	B	Total
9	64.3	35.7	28
10	67.9	32.1	106
11	96.4	3.6	111
12	93.8	6.2	113
13	78.9	21.1	147

considerably from sample to sample. In September and at the beginning of October (sample 9 and 10) we find large percentage number of individuals of the B-type, in the middle of October (sample 11) a very small percentage number and in the two last samples (12 and 13) this growth-type is again represented by larger percentage number of individuals. But it will also be seen that the percentage number of individuals of the B-type is not so large in sample 13 as in sample 9. It is obvious that in a sample which results as a sum of samples 9 and 11 — combined in a ratio at the present unknown — we may find the ratio between the number of individuals of the two growth-types like that in sample 12 or 13.

Finally, we will consider the means of l_1, l_2 and l_3 for the A-type of the year-class 1913 (Table 24). It will be seen that the mean values increase from sample 9 to sample 11 and decrease from the latter sample

Table 24. Mean values in cm. of l_1, l_2 and l_3 for the A-type of the year-class 1913 as fat herring. N stands for the number of individuals examined.

Sample No.	l_1	l_2	l_3	N
9	6.2	12.0	16.7	18
10	6.7	13.3	18.2	72
11	9.0	17.1	22.5	107
12	8.5	16.4	21.6	106
13	7.3	14.6	20.0	116
(10 + 11)1	8.5	16.3	21.6	
(10 + 11)2	7.5	14.6	19.7	

to sample 13. The A-type is, thus, in sample 11 represented by faster growing individuals than in sample 9, and in the other samples we find intermediate mean values.

These facts indicate that two contingents of the fat-herring are represented in these waters. These contingents are found most homogeneously in sample 9 and sample 11. If this is the real fact, however, these two samples (9 and 11) combined in a certain ratio must show the very same age-distribution and the very same growth as for instance sample 13. The following examinations prove that this hypothesis is correct. Attention must be called to the fact that the comparison must be applied to the very same masses. It is not correct, for instance, to compute the combination ratio by means of the age-distribution of the total samples and, afterwards, to examine if this ratio gives the same values of l_1, l_2 and l_3 for the A-type, because the different samples are not composed in the same ratio of the two growth-types (see Table 23). In what follows we will, therefore, consider only the masses which consist of individuals of the A-type. The age-distributions are then given in Table 22 and the growth in Table 24. As representatives of the two contingents of the fat-herring it were better to choose samples 9 and 11. The year-class 1913 is, however, in sample 9 represented by such a small number of individuals that the calculations may be subject to great errors. For that reason, we will choose sample 10 instead of sample 9. As mentioned above, these two samples agree well with each other.

If the real fact is that sample 12 represents a shoal of herring which results as a sum of the shoals which are represented by samples 10 and 11, sample 12 must be obtained by combining samples 10 and 11 in a certain ratio. For the purpose of calculating this ratio, we will use the age-distributions. In the equation below 35.3, 86.3 and 75.2 stand for the percentage number of individuals belonging to the A-type of the year-class 1913 (Table 22).

$$35.3 \cdot x + 86.3 \cdot (1 - x) = 75.2$$

From this we find the value of the ratio:

$$x = 0.2157 \quad \text{and} \quad (1 - x) = 0.7843.$$

If we now combine samples 10 and 11 in this ratio, we find that in the resulting sample the year-class 1914 amounts to 14.0 %, while 18.4 % is found in

sample 12. The corresponding figures for the year-class 1912 are 10.7 % and 6.4 %. In this respect there is thus a good agreement between calculated and empirical values. However, the agreement becomes still more striking if we — according to the same ratio — calculate the values of l_1, l_2 and l_3 for the A-type of the year-class 1913 (see Table 24). It will be seen that for the two samples 10 and 11 together (10 + 11, 1) we find the very same means of l_1, l_2 and l_3 as for sample 12.

In just the same way we will examine sample 13. The combination ratio has to be calculated by the following equation:

$$35.3 \cdot x + 86.3 \cdot (1 - x) = 53.0$$

in which 35.3, 86.3 and 53.0 stand for the percentage number of individuals of the year-class 1913 in samples 10, 11 and 13 (Table 22). We find:

$$x = 0.6529 \text{ and } (1 - x) = 0.3471.$$

According to this ratio we find for the percentage number of individuals of the year-class 1914 42.2 %, while we have found 43.8 % in sample 13. The corresponding figures for the year-class 1912 are respectively 4.8 % and 3.2 %. Thus, there is a good agreement between calculated and empirical values. Moreover, it will be seen from Table 24 that there is a very good agreement between the means of l_1, l_2 and l_3 in sample 13 and in sample (10 + 11, 2).

We have gone further into this matter. Thus, we have tried to characterize the frequency distribution of l_1, l_2 and l_3 for the samples which result through a combination of sample 10 and 11 according to the above mentioned ratios, and we have experienced that the characterizing quantities agree well with the corresponding quantities for samples 12 and 13. Here we will mention, only, that the standard deviation for the frequency distribution of l_1 in sample (10+11, 1) is equal to 1.5 cm. The standard deviation for the frequency distribution of l_1 in sample 12 is equal to 1.5 cm. Thus we see that there is also a very good agreement between the values of this quantity. However, there is no reason to give any particular account of these investigations. The agreement which has been found between the means of l_1, l_2 and l_3 in sample 12 and 13 on the one hand and (10 + 11, 1) and (10 + 11, 2) on the other, must be taken as a proof that there occur two groups of the A-type of the year-class 1913 in these waters.

During September and the beginning of October the fat herring shoals in these waters contain mainly $1^1/_2$ year old individuals (year-class 1914) and in smaller quantities $2^1/_2$ years old individuals (year-class 1913). Moreover, the A-type of the year-class 1913 is represented by relatively slow growing herring. During October, however, shoals with essentially different age-distribution ($2^1/_2$ and $3^1/_2$ year old herrings) appear. In these shoals the year-class 1913 is represented by faster growing herring than those already present in the waters. Table 23 seems to indicate that the year-class 1913 of this new contingent is represented by only the A-type. We will not, however, go further into this matter here. The following investigation of other fat-herring samples collected in the same year (1915) gives interesting contributions to the explanation of these facts.

The samples examined above have been collected in nearly the same locality. However, we have also at our disposal some other samples of fat-herring collected in the same year, which we are now going to examine in the same way. It will be seen from Fig. 9 that sample 8 has been collected in a more southern locality than samples 9—13. Table 21 shows that the age-distribution of this sample agrees well with that of samples 9 and 10. Thus, the year-class 1914 is the dominating one. Moreover, it will be seen from Table 25 that the age-distribution for the A-type is nearly the same as that of sample 10, and in addition we find that the percentage number of individuals of the B-type of the year-class 1913 is 28.2 %, while 32.1 % is found for sample 10 (Table 23). The similarity between these two samples becomes still more striking when we compare the mean values of l_1, l_2 and l_3 for the A-type of the year-class 1913 (see Table 26). These facts must be taken as a proof that sample 8 represents the same contingent of the fat-herring as samples 9 and 10.

Table 25. Percentage composition of the stock of the A-type in year-classes. Fat-herring 1915.

Sample No.	Year-class 1914	1913	1912
8.....	78.1	21.5	0.4
10.....	64.7	35.3	—

Table 26. Mean values in cm. of l_1, l_2 and l_3 for the A-type of the year-class 1913. N stands for the number of individuals examined.

Sample No.	l_1	l_2	l_3	N
8.....	6.8	13.3	18.7	56
10.....	6.7	13.3	18.2	72

Table 27. Percentage composition of the stock of the A-type in year-classes. Fat-herring, 1915.

Sample No.	Year-class 1914	1913	1912
7.....	45.2	53.8	1.0
13.....	43.8	53.0	3.2

Sample 7 is collected in a locality on the Helgeland coast (Fig. 9). This sample contains, in reality, three samples, but they are so similar that we see no reason for discussing them separately. They have also been collected in nearly the same locality and at about the same time. Table 21 shows that the age-distribution is nearly the same as of sample 13, and it will be observed from Table 27 that the age-distribution for the A-type is equal in these two samples. This similarity also applies to the ratio between the number of individuals of the A-type and the B-type of the year-class 1913. The B-type amounts to 27.1 %

in sample 7 and to 21.1 % in sample 13. If we, moreover, consider the mean values of l_1, l_2 and l_3 we find the best agreement. This will be seen from Table 28.

Table 28. Mean values in cm. of l_1, l_2 and l_3 for the A-type of the year-class 1913. N stands for the number of individuals examined.

Sample No.	l_1	l_2	l_3	N
7.....	7.4	14.6	20.2	318
13.....	7.3	14.6	20.0	116

We are, therefore, going to investigate whether the shoal represented by sample 7, originates as a sum of shoals congruent with those represented by samples 10 and 11, in just the same way as we have investigated the samples 12 and 13. Consequently, we calculate the combination ratio by the equation:

$$35.3 \cdot x + 86.3 \cdot (1 - x) = 53.8$$

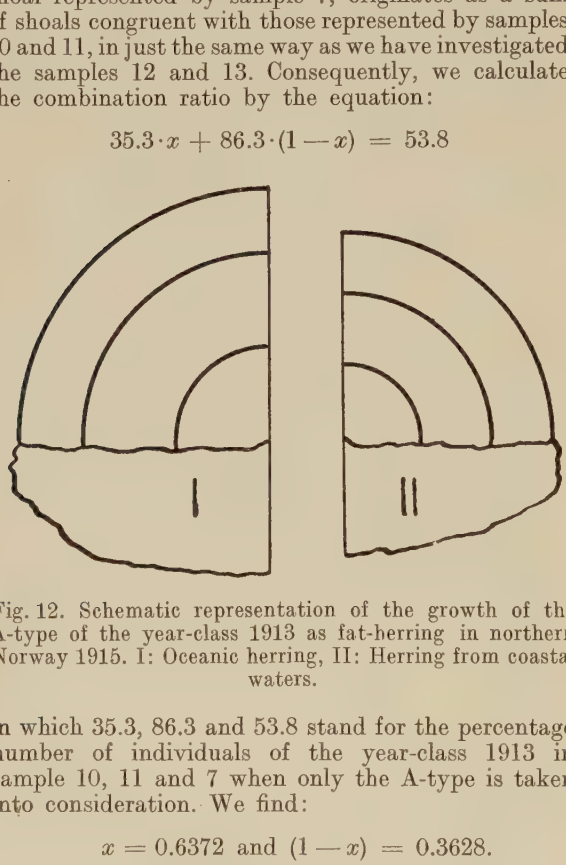

Fig. 12. Schematic representation of the growth of the A-type of the year-class 1913 as fat-herring in northern Norway 1915. I: Oceanic herring, II: Herring from coastal waters.

in which 35.3, 86.3 and 53.8 stand for the percentage number of individuals of the year-class 1913 in sample 10, 11 and 7 when only the A-type is taken into consideration. We find:

$$x = 0.6372 \text{ and } (1 - x) = 0.3628.$$

In the sample which originates as a sum of sample 10 and 11 combined in this ratio, the year-class 1914 (A-type) amounts to 41.2 % and the year-class 1912 to 5.0 %. The corresponding figures for sample 7 are 45.2 % and 1.0 %. These figures, thus, agree well. Moreover, it will be seen from Table 29 that the mean

Table 29. Mean values in cm. of l_1, l_2 and l_3 for the A-type of the year-class 1913.

Sample No.	l_1	l_2	l_3
10.....	6.7	13.3	18.2
11.....	9.0	17.1	22.5
10 + 11	7.5	14.7	19.8
7.....	7.4	14.6	20.2

values of l_1, l_2 and l_3 for the A-type of the year-class 1913 in sample (10 + 11) are the same as those in sample 7. Undoubtedly, we are therefore in these southern waters met with the very same contingents of the fat-herring which we have found represented in the northern waters (samples 9—13).

Fig. 12 gives a schematic picture of the growth of the two contingents of the fat-herring, one being represented by the A-type in sample 11 of the year-class 1913 and the other by the A-type in sample 10 of the same year-class.

The remaining sample (14) is collected in a more northern locality than the other samples from the autumn of 1915 (Fig. 9). Table 21 shows that the year-class 1913 is the dominating one. This also applies to the age-distribution for the A-type, since the year-class 1914 amounts to 21.4 %, the year-class 1913 to 78.6 % and the year-class 1912 is not represented at all. The age-distribution for the A-type is, in other words, the same as in sample 12 (Table 22). In other respects, however, there are great divergencies between these two samples. Thus, it will be seen from

Table 30. Mean values in cm. of l_1, l_2 and l_3 for the A-type of the year-class 1913. N stands for the number of individuals examined.

Sample No.	l_1	l_2	l_3	N
14.....	6.9	13.2	18.6	141
12.....	8.5	16.4	21.6	106
10.....	6.7	13.3	18.2	72

Table 30 that the mean values of l_1, l_2 and l_3 for the A-type of the year-class 1913 are greater in sample 12 than in sample 14. We have also included sample 10 in this Table, and we see that the mean values of l_1, l_2 and l_3 in this sample are just the same as in sample 14. From this fact we must conclude that in this northern district the shoals are represented by the contingent which in more southern districts is represented by sample 9 and 10.

Table 31. Mean values in cm. of l_1, l_2 and l_3 for the B-type of the year-class 1913 as fat-herring.

Sample No.	l_1	l_2	l_3	N
7.....	6.9	12.6	19.4	11
10.....	6.4	11.3	17.0	3
13.....	6.7	11.9	17.8	3
14.....	6.5	11.9	18.2	9

Table 31 shows the growth of the B-type in those samples in which the number of individuals of this growth-type is rather large. This Table indicates that the same growth-group is found in sample 10, 11 and 14. There are slight differences, but on the other hand the material is so small that no conclusions can be drawn from these differences. It seems, however, that the B-type in sample 7 is represented by faster growing individuals. Both l_1, l_2 and l_3 have greater mean values in this sample than in the first mentioned ones. But as will be proved by the following examination, the material is too small as a basis of the

conclusion that the B-type also, can be separated into two growth-groups. We will compare the samples in which the number of individuals is largest (7 and 14). Table 32 shows the mean values of t_1 and t_2 and,

Table 32. Mean values (m) in cm. of t_1 and t_2 for the B-type of the year-class 1913. μ stands for the standard deviation of the mean and N for the number of individuals examined.

Sample No.	t_1		t_2		N
	m	μ	m	μ	
7.....	6.9	0.067	5.7	0.069	118
14.....	6.5	0.081	5.4	0.071	95

in addition, the standard deviation of these means. We find for t_1 the difference 0.4 cm. and for t_2 the difference 0.3 cm. These differences are when measured with their standard deviations, equal to 3.8 and 3.0 respectively. Consequently, we cannot definitely decide whether these differences would be eliminated or reversed if new observation data were collected. The material is too small as a basis of such a conclusion.

The comparison between the growth of the A-type and that of the B-type is very difficult in this case because the A-type in most samples is composed of two essentially different contingents. The A-type in sample 10 and 14, however, belongs wholly or almost wholly to be the coastal contingent. It will be observed from Table 33 that in both these samples the mean

Table 33. Mean values in cm. of t_1 and t_2 for the growth-types A and B. N stands for the number of individuals examined.

Growth-type	Sample No. 10			Sample No. 14		
	t_1	t_2	N	t_1	t_2	N
A	6.7	5.6	72	6.9	6.3	141
B	6.4	4.9	34	6.5	5.4	95

values of t_1 and t_2 are greater for the A-type than for the B-type, while on the other hand, the mean values of these quantities are nearly the same in the two samples when we consider the two growth-types separately. This seems to indicate that also for the year-class 1913 there are growth-differences in the first years between the A-type and the B-type. As mentioned above, sample 7 has been collected in a more southern locality than samples 10 and 14. The mean values of t_1 and t_2 for the B-type in this sample are 6.9 cm. and 5.7 cm. respectively. The mean increments in the first two years of life for the B-type in the southern waters are, accordingly, nearly the same as for the A-type in the northern waters. This fact may give an explanation of the "marking" phenomenon — in this case that the length increment in the 3rd year is greater than that in the second year of life. The growth-rate seems to indicate that the B-type in sample 7 has spent the first two years of life in the very same waters as the A-type in sample 10. If this explanation is correct, the growth-mark is due to migrations from a northern district to a southern district of the coastal waters. However, the growth difference between the A-type and the B-type of the coastal contingent is rather small when compared with the difference which appears between the coastal herring and the oceanic herring.

Among the other year-classes present in 1915 the year-class 1912 is represented by such a small number of individuals that reliable growth investigations are not feasible. The year-class 1914 is in some samples represented by a large number of individuals, but, on the other hand, it is probable that a selection has taken place, because these individuals are rather small owing to their young age. It is likely that a rather great percentage of the individuals of this year-class has not yet become fat-herring. For this reason the investigation of the growth of this year-class gives no reliable results.

The fat-herring samples from the autumn of 1915 give an illustrating example of the immigration of oceanic herring to the coastal waters. There is no doubt that we are here confronted with such an immigration. We see that the oceanic contingent of the fat-herring appears both on the Helgeland coast (sample 7) and in Vesterålen (sample 9—13). Moreover, it may be said to be an experience of old standing that oceanic herring make their appearance in some years and in some coastal districts (see f. i. Hjort 1895). The general importance of the oceanic herring for the yield of the fat-herring fishery cannot be stated on the basis of the material at our disposal. Lea (1929), however, seems to attach a very great importance to the oceanic contingent. At any rate there is no doubt that the immigration of oceanic herring was of very great importance for the yield of fishery in the year 1915.

The Year-class 1918.

From the autumn of 1920 we have also a rather interesting material of the fat-herring at our disposal. Table 34 shows that year-class 1918 is the domi-

Table 34. Percentage composition of the stock of fat-herring in the year-classes. 1920.

Sample No.	Date	Year-class					Total
		1920	1919	1918	1917	1916	
15.....	$^{18}/_{8}$	—	1.1	94.9	4.0	—	175
16.....	$^{7}/_{10}$	2.5	54.1	43.4	—	—	244
17.....	$^{16}/_{8}$—$^{1}/_{9}$	—	9.7	85.9	3.7	0.7	739
18.....	$^{24}/_{8}$—$^{10}/_{9}$	—	2.4	87.8	8.4	1.4	929

nating one in three of the samples (15, 17 and 18), while in sample 16 the year-class 1919 amounts to more than fifty per cent. of the individuals. Fig. 9 shows that sample 16 is collected in a more southern locality than the other samples. It should be borne in mind, however, that sample 17 results as a sum of four different samples which have been taken in the same locality at almost the same time, and which in regard to age-composition as well as growth of the different biological groups, show a perfect similarity.

In the same way sample 18 is the sum of five different samples which have been taken in the same locality and which show a very good conformity with respect to age-composition. As will be shown later on, however, there are differences in the growth. In the following we are confining ourselves to the year-class 1918.

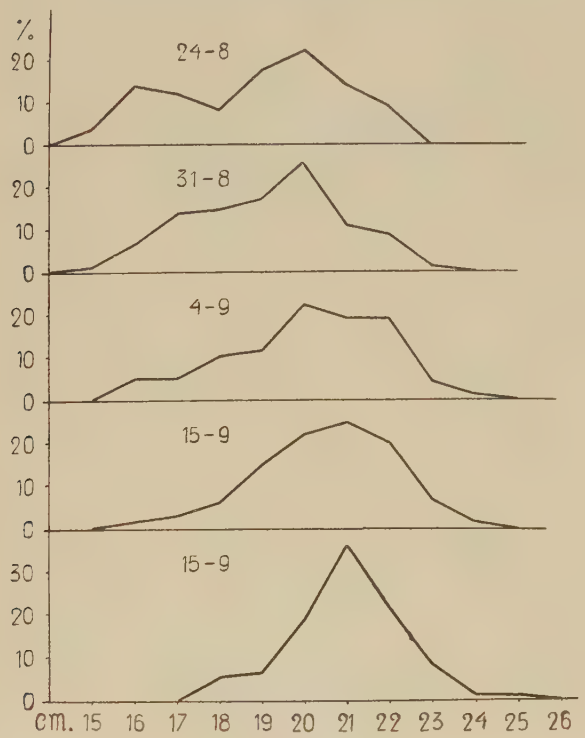

Fig. 13. Frequency curves for the length of herrings of the A-type of the year-class 1918 as fat-herring. Sample No. 18, 1920.

Table 35. Mean values in cm. of t_1, t_2 and t_3 for the year-class 1918 as fat-herring 1920.

Sample No.	A-type			B-type		
	t_1	t_2	t_3	t_1	t_2	t_3
15	9.1	5.9	4.8	8.1	4.7	5.3
16	9.2	6.2	4.8	8.1	5.1	5.6
17	9.1	5.9	4.8	8.3	4.8	5.5

The B-type of the year-class 1918 is represented by 15.1 % in sample 15, 18.9 % in sample 16, 20.2 % in sample 17 and 9.1 % in sample 18. Table 35 shows the growth of the A- and B-types in the samples 15, 16 and 17. As regards sample 17 it is to be noted that the original four samples show the most satisfactory agreement as to growth. This table shows that the mean yearly increments i. e. t_1, t_2 and t_3, are exactly the same in all the 3 samples when comparing each growth type separately. If we compare the two growth types we find that the increments in the first two years of life are greater for the A-type than for the B-type. The differences are almost the same in the various samples and point in the same direction. The increment in the third year of life is, however, greater for the B-type than for the A-type, but also in this case the differences are almost identical in the various samples and point in the same direction.

Table 36. Mean values in cm. (m) of t_1 and t_2 for the year-class 1918 as fat-herring (sample 17). μ stands for the standard deviation of the mean and N for the number of individuals examined.

Growth-type	t_1		t_2		N
	m	μ	m	μ	
A	9.1	0.061	5.9	0.032	507
B	8.3	0.092	4.8	0.052	128

Table 36 shows in addition to the means of t_1, and t_2 the standard deviation of these means (sample 17). When comparing the two growth types (A and B) the following differences will be found: for t_1 0.8 cm. and for t_2 1.1 cm. Measured with their standard deviations these differences are equal to 7.3 and 18.0 respectively. There is, therefore, only a small probability of these differences being eliminated or reversed if new observation data were collected under the same conditions. We have shown above that the differences in the three samples are almost the same and point in the same direction and this fact leads to the conclusion that the A-type during its first and second year has grown essentially faster than the B-type.

Table 37. Mean values in cm. of l_1, l_2 and l_3 for the A-type of the year-class 1918. Sample No. 18, 1920.

Date	$^{24}/_{8}$	$^{31}/_{8}$	$^{4}/_{9}$	$^{15}/_{9}$	$^{15}/_{9}$
Mean l_1	9.6	9.6	10.2	10.0	10.2
— l_2	15.1	15.3	15.9	16.0	16.4
— l_3	18.9	19.2	20.1	20.5	21.0

An examination of sample 18 shows that other facts are involved here. As mentioned above this sample consists of five different samples taken in nearly the same locality, but at different times. Table 37 shows the means of l_1, l_2 and l_3 (l_3 in this case representing the actually measured length) for the A-type in these samples. It will be noticed from this that the means increase from the first to the last sample. The explanation of this variation will be seen in Fig. 13 where the frequency curves of the length (l_3) for the A-type are drawn, and it appears that in the first sample (August 24th) at least two size-groups are represented. It will, however, also be seen that one of these groups which are distributed round about the lowest mean disappears gradually in the later samples in such a way that in the last sample (September 15th) practically only the other group remains. It cannot, however, be taken for granted that the group distributed about the lowest mean disappears from the water, because the different samples have not been taken at exactly the same place in the same fiord (Altenfjord). But there is no doubt that the A-type of the year-class 1918 as fat-herring in this district (sample 18) is

represented by two different size-groups, whose growth is essentially different.

In the material from the autumn of 1915 we have previously shown some facts of the same kind. We noticed how large fast growing individuals of the year-class 1913 joined the fat-herring shoals already present in the coastal waters, and we concluded that this immigration originated from the open sea. In this year the fat-herring were represented by two different contingents. This, evidently, was the fact also for the fat-herring shoals in the district where sample 18 had been collected in the autumn of 1920. It is inconceivable that the large fast-growing individuals which we find in this sample should have grown up in the coastal water. It must be supposed that these herring, in the time prior to the samples having been collected, have immigrated from the sea and mixed with the coastal herring in the same way as in 1915.

There remains now an interesting and important question: whether the large fast-growing individuals of the year-class 1918 in the autumn of 1920 belong to the same contingent of the Norwegian herring stock as that of the large fast-growing herring of the year-class 1913 which appeared in the material from the autumn of 1915. The present material is, of course, not sufficient to settle this question. We are undoubtedly confronted with an immigration of oceanic herring; but contrary to the facts in the autumn of 1915 this immigration has, however, only been noticed in the most northern locality (see Fig. 9). This indicates that the immigration in the autumn of 1920 originates from more northern areas of the ocean. In the following we are going to show that herring with a very fast growth are also to be found in the Barents Sea. As to whether there is any connection between the herring from the Barents Sea and the large fat-herring in sample 18 or not we cannot, of course, express any positive opinion. We only want to point out this as a probable explanation worthy of a closer examination.

Herring from Petsamo.

We have here at our disposal a sample of herring from Petsamo (November 27th 1931) which shows very interesting facts. As a single sample, however, is not sufficient as a basis for a thorough examination of the growth of herring in this locality, we confine ourselves to the consideration of the growth of a single year-class i. e. that of 1929. It will be seen from table 38 that the mean increments in length are very great. In this case, however, it is not certain that the means are absolutely representative, because the material seems to indicate that a selection has taken place in such a way that the smallest herring have not been caught. However, when the frequency distribution of l_1 (Fig. 14) is considered it will be seen that even individuals with l_1 equal to 14.5 cm. are represented. This must be taken as a proof of extensive drifting and of large migrations, it being inconceivable that these fast-growing individuals have grown up in this northern area of the ocean. We are, however, forced to content ourselves with the fact that we have proved the existence of these large fast-growing herring. It must be left to future investigations to solve the problems, which arise from this experience.

Table 38. Mean values in cm. of t_1, t_2 and t_3 for the A-type of the year-class 1929 in a sample of herrings from Petsamo, $^{27}/_{11}$, 1931.

t_1	t_2	t_3	N
11.0	7.2	4.4	30

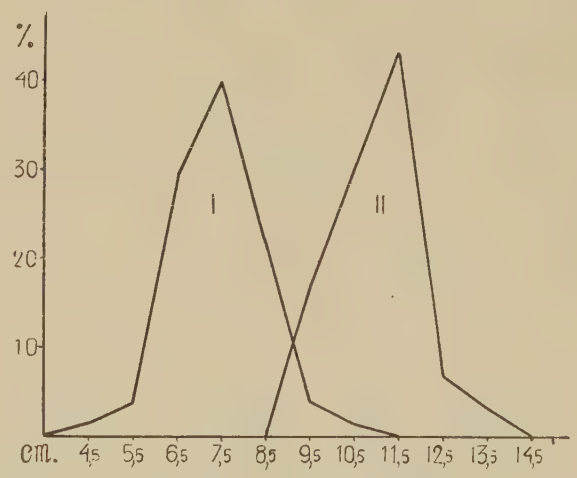

Fig. 14. Frequency curves for t_1. II: A-type of the year-class 1929 from Petsamo. I: A-type of the year-class 1904 as fat-herring from northern Norway.

CHAPTER V

The stock of Norwegian large and spring-herring.

The Norwegian large and spring-herring are the objects of very important fisheries along the Norwegian coast. As a rule, the large-herring fishery begins somewhat earlier in the year than the spring-herring fishery. There is also some difference as to fishing grounds, inasmuch as the large-herring are caught in more northern districts than the spring-herring. Table 39 shows the yields of fishery of the two kinds of herring in various districts (Fylke) along the coast from south to north in a single year. This table does not pretend to illustrate the typical facts, but only the distribution of the yields of fishery in the year 1928. As regards the fishing grounds the spring-herring fishery is on the whole very constant from one year to another, while the large-herring fishery is more variable.

Table 39. Total quantity in hectolitres of spring-herring and large-herring landed in Norway in the year 1928.

Fylke (district)	Spring herring	Large herring
Vest-Agder	53,050	
Rogaland	1,273,000	
Hordaland	360,000	
Bergen	220,000	
Sogn og Fjordane	131,981	179,478
Møre	12,843	751,829
Sør-Trøndelag		15.701
Nord-Trøndelag	10	
Nordland	100	

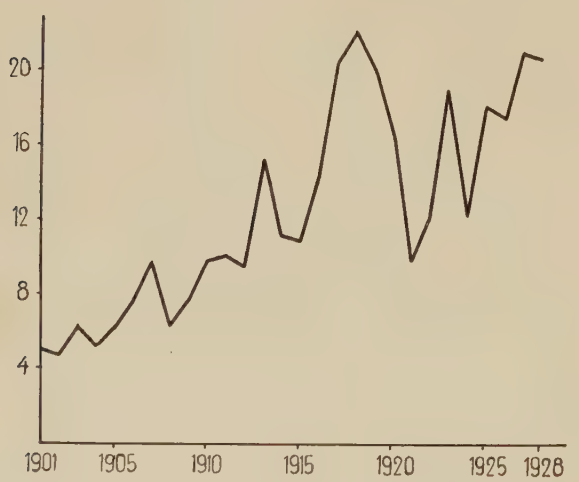

Fig. 15. Total quantity in 100,000 hecto-litres of spring herring landed in Norway in the years 1901—1928.

The quantities caught of large-herring and spring-herring vary considerably from year to year. This fact has been known for a very long time. In Fig. 15 we have given an illustration of the fluctuations as regards the spring-herring. It will be seen, for instance, that the quantity caught in 1918 is almost four times as great as that caught in 1908. The chief causes of these fluctuations are mainly the great variations in the number of individuals in the various year-classes. Experience shows that from the very moment a numerous year-class joins the large and the spring-herring shoals, good yields can be expected for a number of years to come.

The large-herring and the spring-herring are both mature fish. The age-composition may vary in the various samples, but apart from the samples of recruit-spawners (Lea 1929, 2), we usually find individuals from 4 years of age to the highest age attained by herring. In comparison to the fat-herring stock, the stock of the large and the spring-herring is very uniform from year to year as well as from locality to locality. The fluctuations in the number of individuals in the various year-classes must, however, be borne in mind. There is much greater reliability in using one or some few samples as representative of the spring-herring stock than in using a few samples as that of the fat-herring stock. But even with the spring-herring and the large-herring the utmost precaution is necessary.

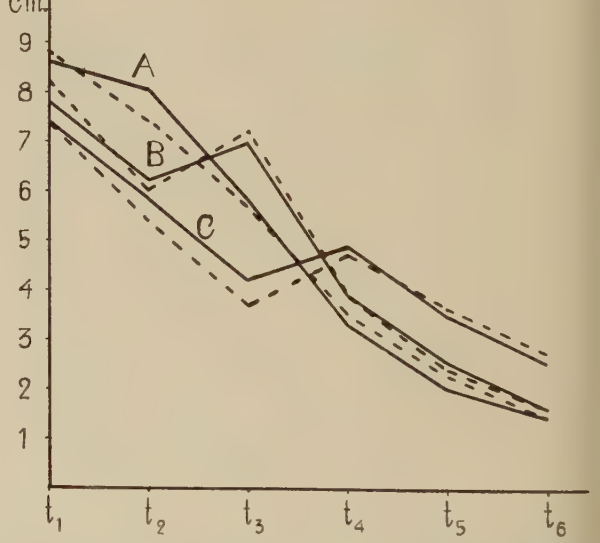

Fig. 16. Graphic representation of the mean yearly increments in length of the year-class 1904 — growth-types A, B and C —. ———— large-herring 1909, — — — — large-herring 1915.

If we are concerned with studies of growth, however, experience shows a striking uniformity. On this subject we will confine ourselves to refer to chapter II, Table 9. In this case, concerning the growth of herring of the year-class 1904, a single or some few samples will constitute a sufficient basis for a correct illustration. But even in such cases the uniformity ought to be proved empirically and cannot be assumed without any investigation. In most cases, however, it is impossible to procure such a comprehensive material as that of this year-class.

In samples both of large-herring and of spring-herring we find that the same growth-types are represented which were found in the samples of fat-herring, i. e. the growth-types A, B and C. As regards the spring-herring also another growth-type is represented which is characterized by the length increment in the first year of life being smaller than that in the second year. In our material, however, this growth-type is represented by such a small number of individuals that we will leave it out of consideration.

The following investigation shows that the growth of the three growth-types A, B and C is essentially different. Thus, the A-type has greater increment in the first two years of life than the B-type and the C-type. Whether the two latter growth-types also differ essentially as regards the growth in the first years of life cannot always be ascertained, but various facts point in that direction. The fact that two groups of herring have different growth in the first years of life, indicates that they originate in different spawning areas, or at least, that they have spent their first years of life in different areas of the sea. Consequently, the migrations of these groups on their way to the spawning grounds have been different. To throw light upon these problems is of the greatest importance for the understanding of the life history of the herring, and we shall revert to them later on in more detail.

In what follows we will examine the growth of some year-classes of the Norwegian large-herring and spring-herring by the method of dividing the material — as in the case of the fat-herring — into the three growth-types A, B and C.

The year-class 1904.

As mentioned above the year-class 1904 is characterized by its unusually large number of individuals. The Norwegian investigations have shown that this year-class dominated in the shoals of large and spring-herring for a series of years (see LEA 1930). First, we will consider it as large-herring. Our material contains two samples from 1909 and four samples from 1915. The two samples from 1909 are taken in the autumn (September and October) in drift-nets. The samples from 1915 are taken in winter in the same locality and at nearly the same time, and we will therefore examine them together. The year-class 1904 dominated in all samples and amounted to 60 % in 1909 and to 57 % in 1915.

In Table 40 the number of individuals of the year-class 1904 is given, and in addition the percentage

Table 40. Percentage composition in growth-types of the stock of the year-class 1904 as large-herring.

Year	Sample No.	A	B	C	Total
1909.....	19+20	68.3	20.1	11.6	442
1915.....	21	45.8	5.1	49.1	491

of this number which stands for the various growth-types. It ought to be mentioned here that there is a great similarity between the two samples from 1909 in regard to this distribution. This applies also to the four samples from 1915. It will be seen from this table that the C-type was of much greater importance in 1915 than in 1909. Provided our samples are representative of the stock, this change can only be explained by an immigration of herrings of the C-type to the large-herring shoals during the years from 1909 to 1915. It will be shown below that a corresponding immigration has taken place to the spring-herring shoals.

Fig. 16 gives a graphical illustration of the yearly increments in length of the three growth-types. Here, we have taken the two samples from 1909 together and likewise the four samples from 1915. It will be seen from this diagram that the growth curves for each of the three growth-types are almost identical in the two years. Between the various growth-types, however, great differences appear. In the first two years of life the A-type has the greatest increments, in the third year the B-type and in the fourth and the following years the C-type. The length increments in the first two years are also here of paramount interest since they may be taken as an outcome of the environments in which these growth-types have spent their first years of life. We will therefore examine these increments more closely.

Table 41. Mean values in cm. of t_1 and t_2 for growth-types A, B and C of the year-class 1904 as large-herring.

Year	Sample No.	t_1 A	t_1 B	t_1 C	t_2 A	t_2 B	t_2 C
1909.....	19	8.7	7.8	—	8.0	6.2	—
—	20	8.6	7.8	7.4	7.8	6.1	5.8
1915.....	21	8.8	—	7.6	7.4	—	5.3
—	—	8.8	—	7.5	7.3	—	5.4
—	—	8.7	—	7.3	7.4	—	5.3
—	—	8.8	7.9	7.3	7.6	6.0	5.1

Table 41 gives the means of t_1 and t_2 for the three growth-types in the various samples. Where no mean is given, the number of individuals is rather small. As regards t_1, it is striking how closely the means coincide for each growth-type in the various samples, a fact which definitely indicates that these means are very close to the real values. But still another and very important rule can be deduced from this table, i. e. in all samples the mean for the A-type is greater than that for the B-type and this again greater than that for the C-type. This clearly indicates that the areas of the sea in which the growth-types have spent their first year of life, present essentially different

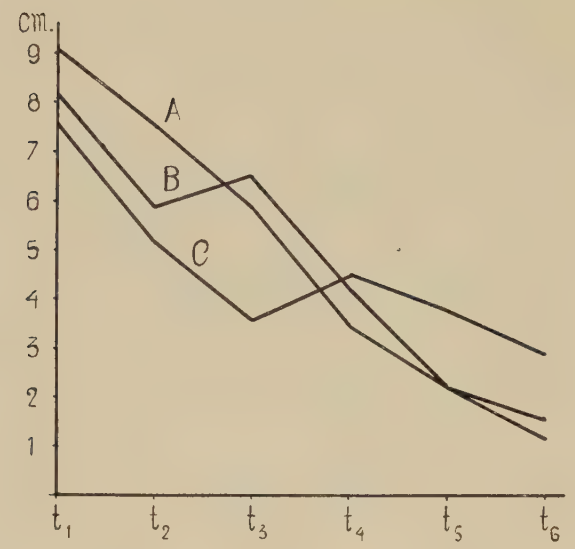

Fig. 17. Graphic representation of the mean yearly increments in length of the year-class 1904 as spring herring (1909—1916).

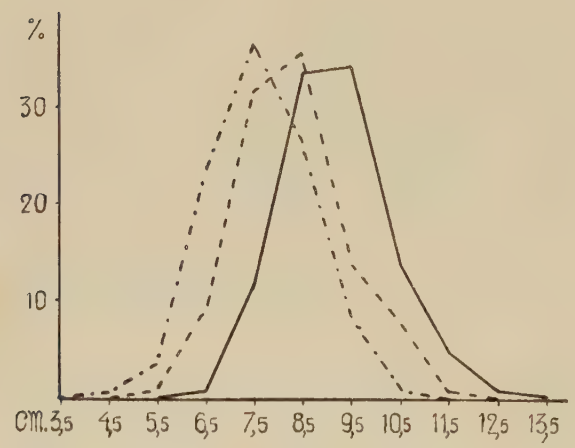

Fig. 18. Frequency curves for t_1 of the year-class 1904 as spring-herring. ———— growth-type A, — — — — growth-type B, —.—.—.— growth-type C.

conditions for growth. The same holds good for t_2, although we find small differences between the means in the two years. These differences are not so great, however, that they are of any great importance, especially since the number of individuals examined, for which the means have been calculated, in most samples is rather small.

Since the various samples show extremely good similarity we will in the following consider them collectively. Table 42 gives the means of t_1 and t_2 for all samples together. The standard deviations of these means are also given in this table. If we compare the means of the three growth-types, we find the

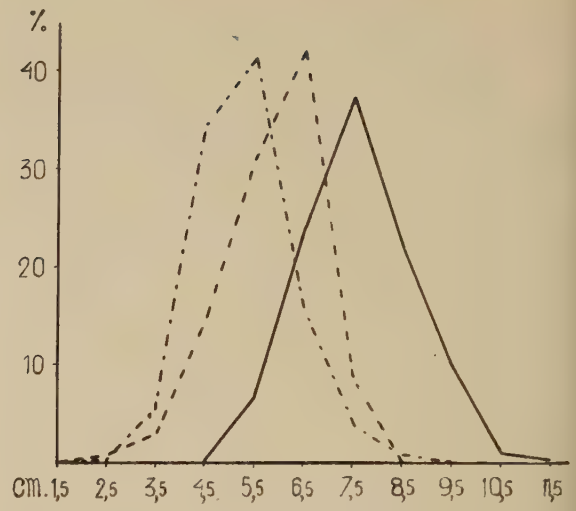

Fig. 19. Frequency curves for t_2 of the year-class 1904 as spring-herring. ———— growth-type A, — — — — growth-type B, —·—·—·— growth-type C.

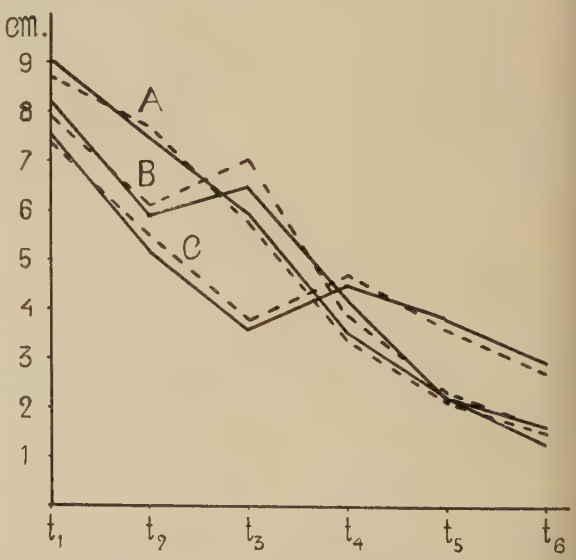

Fig. 20. Graphic representation of the mean yearly increments in length of the year-class 1904 (Total material). ———— spring-herring, — — — — — large-herring.

Table 42. Mean values in cm. (m) of t_1 and t_2 for the growth-types A, B and C of the year-class 1904 as large-herring. μ stands for the standard deviation of the mean and N for the number of individuals examined.

Growth-type	t_1		t_2		N
	m	μ	m	μ	
A	8.7	0.052	7.7	0.057	527
B	7.9	0.095	6.1	0.083	115
C	7.4	0.060	5.5	0.057	291

Table 43. d stands for the absolute difference and d' for this difference measured with its standard deviation. See text.

Growth-types compared	t_1		t_2	
	d	d'	d	d'
A and B	0.8	8.0	1.6	15.8
A and C	1.3	16.4	2.2	27.2
B and C	0.5	4.5	0.6	5.9

absolute and relative differences given in Table 43. The comparison of the A-type with the two other growth-types gives very great relative differences both for t_1 and for t_2. When we compare these figures with those in Table 41, we must take it for granted that the differences would not be eliminated or reversed if new observations were collected under the same conditions. The probability, at any rate, that this should happen is very small. In other words, the A-type has essentially faster growth in the first two years of life than the other growth-types. The comparison between the B-type and the C-type gives much smaller relative differences, but if we take the facts shown in Table 41 into consideration, they will just as well suffice to permit the conclusion that the B-type has essentially faster growth in the first two years of life than the C-type. In what follows we will show that the same holds good also for the year-class 1904 as spring-herring.

The material at our disposal of the year-class 1904 as spring-herring has been used above in chapter II as a basis for the study of the relation between the growth of the herring and that of its scales. This material contains samples from a series of years. In addition to the growth-types A, B and C another growth-type is represented which is characterized by a smaller length increment in the first than in the second year of life. This growth-type, however, is represented by such a small number of individuals that we will leave it out of the discussion to follow.

Table 44. Percentage number of individuals of the growth-types B and C of the year-class 1904 as spring-herring.

Growth-type	year					
	1909	1911	1912	1914	1915	1916
B	16.9	13.1	19.2	18.6	15.9	12.9
C	1.7	33.2	39.4	39.2	36.6	41.3

Table 44 gives the percentage number of individuals of the growth-types B and C in various years. As regards the B-type this percentage is nearly constant from year to year. There is at any rate no tendency of the variation. The C-type, however, shows a marked increase in the percentage from 1909 to 1912. But from the latter year to 1916 the percentage is very nearly constant. The increase in the percentage number from 1909 to 1912 can only be explained by an immigration of herring of the C-type to the spring-herring shoals during the same time. We have shown above that a corresponding immigration to the large-herring shoals has taken place in the same period.

Table 45. Mean values in cm. of t_1 and t_2 for the growth-types A, B and C of the year-class 1904 as spring-herring.

Sample No.	t_1			t_2		
	A	B	C	A	B	C
24.....	9.5		7.8	7.9		5.6
25.....	8.9	8.0	7.3	7.4	6.0	5.5
27.....	8.7		7.4	7.2		5.3
29.....	8.8	8.0	7.2	7.4	6.0	5.2
32.....	9.0		7.3	7.4		5.3
33.....	9.5	8.8	8.3	7.2	5.7	4.9

Table 45 gives the mean values of t_1 and t_2 for the three growth-types for the samples in which the number of individuals of the growth-types B and C is sufficiently large to attach any importance to the means. We have mentioned above the similarity which the various samples show with regard to the growth. The reason for including this table here is the desire to show that both for t_1 and for t_2 the rule holds good that, in all samples, the mean for the A-type is greater than that for the B-type, and the latter greater than that for the C-type. This fact points to fundamental differences in the growth of the three growth-types. Since the various samples exhibit such similarity, we will take them as one sample. Fig. 17 gives a graphical illustration of the length increments for the three growth-types. This diagram resembles perfectly that in Fig. 16 for the large-herring. The A-type has greatest increments in the first two years of life, the B-type in the third year and the C-type in the fourth and the following years.

The length increments in the first two years of life are of special interest. Fig. 18 and Fig. 19 give the frequency curves of t_1 and t_2 for the three growth-types. It will be seen that the curves are regular and nearly symmetrical and, moreover, that there is a relatively strong displacement in their position.

Table 46. Mean values in cm. (m) of t_1 and t_2 for the growth-types A, B and C of the year-class 1904 as spring-herring. μ stands for the standard deviation of the mean and N for the number of individuals examined.

Growth-type	t_1		t_2		N
	m	μ	m	μ	
A	9.1	0.037	7.5	0.012	875
B	8.2	0.098	5.9	0.087	129
C	7.6	0.045	5.2	0.041	566

Table 46 gives the means of t_1 and t_2 and the standard deviations of these means. The comparison between the three growth-types gives the absolute and relative differences shown in Table 47. It will be observed that the relative differences in all cases are so great that we are permitted to conclude that the probability is very small that these differences would be eliminated or reversed if new observations were collected under the same conditions. As in the case of the large-herring we can, consequently, conclude

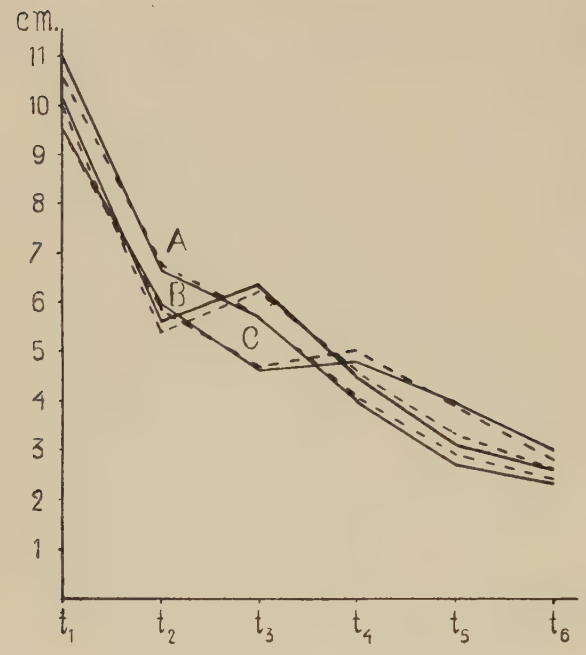

Fig. 21. Graphic representation of the mean yearly increments in length of the year-class 1918. — — — — spring-herring 1925, ———— large-herring 1925.

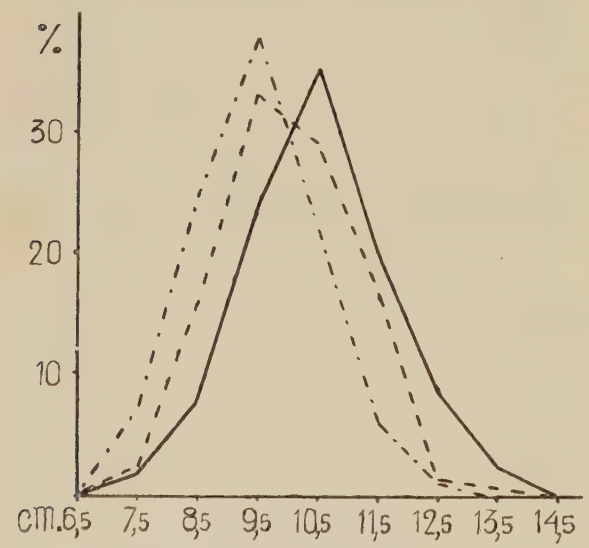

Fig. 22. Frequency curves for t_1 of the year-class 1918 as spring-herring 1925. ———— growth-type A, — — — — growth-type B, —·—·—·— growth-type C.

that there are essential differences between the growth in the three first years of life of the three growth-types. The explanation of these differences must be sought therein that the three growth-types originate in areas of the sea — in this case in areas of the coastal waters — which present essentially different conditions for growth.

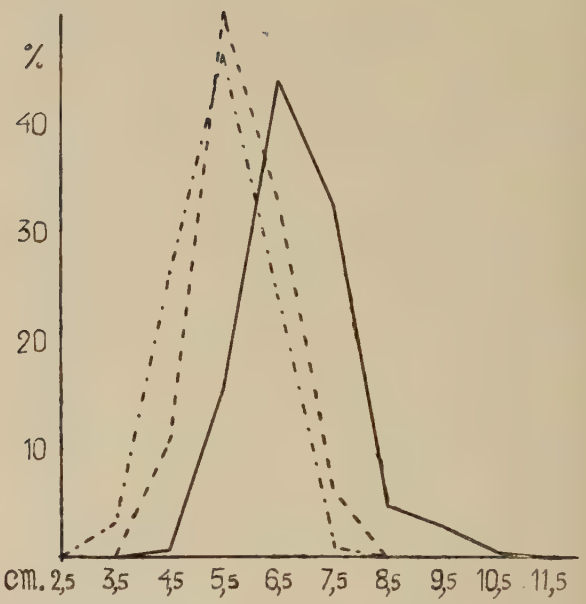

Fig. 23. Frequency curves for t_2 of the year-class 1918 as spring-herring 1925. ———— growth-type A, — — — — growth-type B, —·—·—·— growth-type C.

Table 47. *d* stands for the absolute difference and *d'* for this difference measured by its standard deviation. See text.

Growth-types compared	t_1		t_2	
	d	*d'*	*d*	*d'*
A and B	0.9	8.6	1.6	16.9
A and C	1.5	25.0	2.3	41.8
B and C	0.6	5.6	0.7	7.3

Finally, we will by means of a diagram make a comparison between the growth of the large-herring and that of the spring-herring (Fig. 20). It will be seen that the two growth-curves for the separate growth-types are almost identical. The large-herring and the spring-herring consequently grow at the same rate.

The year-class 1918.

Our material of the year-class 1918 contains three samples of the large-herring and three samples of the spring-herring from January 1925. The three large-herring samples have been collected in the same locality and agree in every respect to such an extent that we will examine them together. This holds good for the spring-herring samples as well. As to age-composition the year-class 1918 dominates in all samples since it amounts to about 50 % both in the large-herring and in the spring-herring samples. Table 48 shows the composition of the stock in growth-

Table 48. Percentage composition of the stock of the year-class 1918 (1925). N stands for the number of individuals examined.

Stage	Growth-type A	B	C	N
Large-herring	49.5	33.9	16.6	271
Spring-herring	43.6	34.9	21.5	372

types. It will be seen that there is a very good agreement between the large-herring and the spring-herring. This applies also to the growth. Fig. 21 shows that the growth-curves for each separate growth-type as large-herring and as spring-herring are almost identical, while there are fundamental differences between the various growth-types. We will, however, in this case also examine the length increments in the first two years of life in more detail. It appears from Table 49 that the mean both of t_1 and of t_2 is greater for the A-type than for the B-type and the C-type, a fact which applies both to the large-herring and the spring-herring. A comparison between the B-type and the C-type shows that the first has greater increment in the first year than the latter, while the opposite fact holds good for the increment in the second year.

Table 49. Mean values in cm. (m) of t_1 and t_2 for the year-class 1918 as large and spring-herring in 1925. μ stands for the standard deviation of the mean and N for the number of individuals examined.

Stage	Growth-type	t_1 m	t_1 μ	t_2 m	t_2 μ	N
Large-herring	A	11.0	0.113	6.7	0.093	134
	B	10.2	0.139	5.5	0.088	92
	C	9.5	0.227	5.9	0.129	45
Spring-herring	A	10.5	0.096	6.8	0.076	162
	B	10.0	0.098	5.4	0.071	130
	C	9.5	0.118	5.8	0.085	80

When we consider each growth-type separately, it will be seen that the mean both of t_1 and of t_2 are almost the same for the large-herring and the spring-herring. This fact indicates that the means are very close to the real values. Fig. 22 and Fig. 23 give graphical illustrations of the frequency distributions of t_1 and t_2 for the three growth-types in the spring-herring sample. The curves are almost symmetrical and very regular. In accordance with the means there are strong displacements in their position.

We are now going to make comparisons between the length increments in the first years of the three growth-types. First, we will consider the large-herring. A comparison between the A-type and the B-type gives for t_1 the difference 0.8 cm. and for t_2 the difference 1.2 cm. Measured with their standard deviations these differences are equal to 4.5 and 9.4 respectively. In this case the relative differences are sufficiently great to permit the conclusion that the growth of the A-type and that of the B-type are caused by essentially different conditions. That this conclusion is correct is also proved by the fact that the differences in each of the original samples, here considered as a whole, point in the same direction. In each separate sample the differences for t_1, are equal to + 0.6 cm., + 0.7 cm. and + 0.9 cm. and for t_2 equal to + 1.2 cm., + 1.4 cm. and + 1.2 cm. respectively. In addition to these facts, the study of the spring-herring gives just the same result. A comparison between the A-type and the B-type gives for t_1 the difference 0.5 cm. and for t_2 the difference 1.4 cm. Measured with their standard deviations these differences are equal to 3.6 and 13.5 respectively. Here also the differences in each separate sample point in the same direction. Thus we find for t_1 — for instance — the differences + 0.5 cm., + 1.0 cm. and + 0.6 cm. A comparison between the A-type and the C-type gives the very same result, viz. that the A-type has essentially greater length increments in the first two years of life than the C-type. But the material is too small to permit any conclusion whether the B-type and the C-type have different growth in the first years.

On the basis of these investigations we can take it for granted that the A-type originates in another area of the coastal waters than the B-type and the C-type. We shall later on revert to these circumstances. Confining ourselves to the consideration of graphical illustrations, we shall in the following prove that just the same rule as has been described above for the year-class 1904 and 1918, also holds good for other year-classes of the Norwegian large and spring-herring.

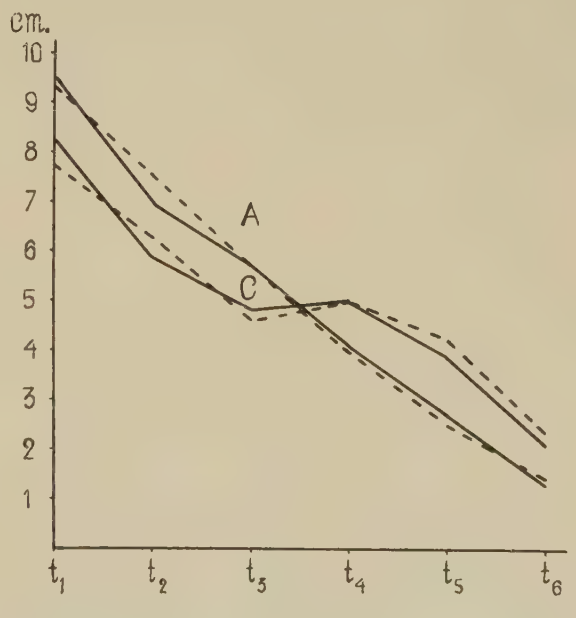

Fig. 24. Graphic representation of the mean yearly increments in length of the year-class 1907. ———— spring-herring, — — — — large-herring.

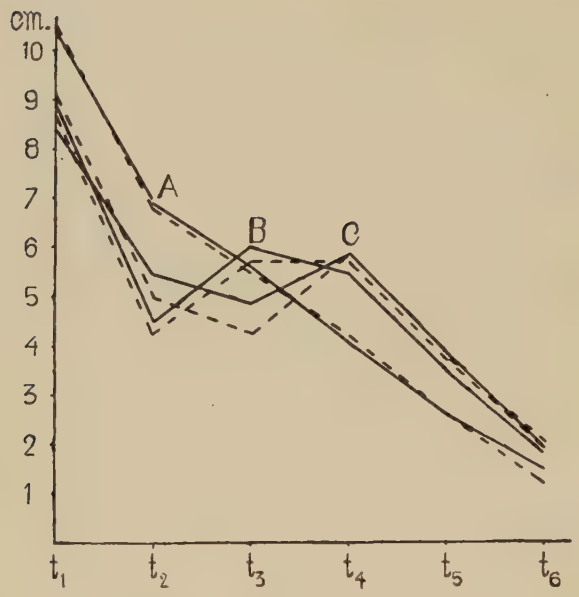

Fig. 25. Graphic representation of the mean yearly increments in length of the year-class 1916. ——— spring-herring, — — — — large-herring.

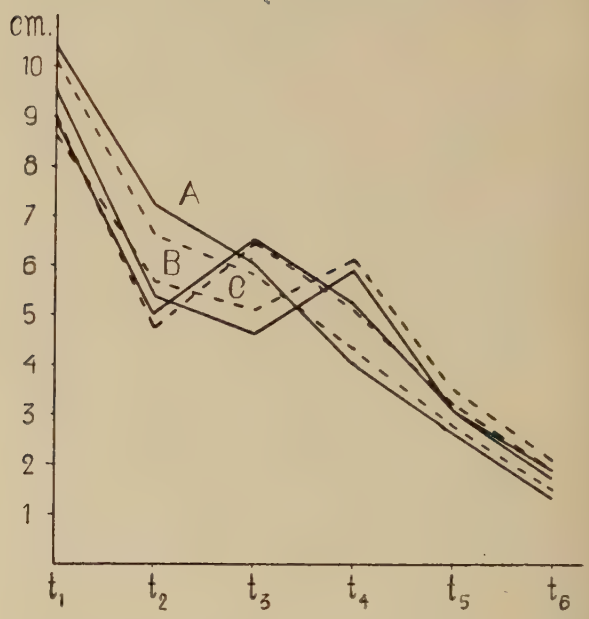

Fig. 26. Graphic representation of the mean yearly increments in length of the year-class 1917. ——— spring-herring, — — — — large-herring.

The year-classes 1907, 1916 and 1917.

Figs. 24, 25 and 26 give graphical illustrations of the length increments in the first six years of life for the growth-types A, B and C of the large-herring and of the spring-herring. As regards the year-class 1907 the B-type has not been included, owing to the small number of individuals. First it will be seen from these figures that the growth-curves for each separate growth-type as large-herring and as spring-herring are almost identical. There are, of course, small differences, but they are very small and do not exceed the statistical errors.

From these figures the rule can be derived that the A-type has the greatest length increments in the first two years of life, the B-type in the third year and the C-type in the fourth and the following years. We have likewise examined the growth of some other year-classes than those mentioned here, and the same rule holds good for them all. In the next chapter we are going to discuss some problems which arise in connection with these growth differences.

CHAPTER VI

On the life history of the Norwegian herring.

Four kinds of herring fishery take place along the Norwegian coast, viz. fishery of small-herring, fat-herring, large-herring and spring-herring. The small-herring fishery takes place almost along the entire coast as far north as Finmark, while the other fisheries are more limited to certain districts of the coast. Thus the fat-herring are chiefly caught in northern districts with the largest quantities in Troms, the large-herring are caught off the coast of Møre and Trøndelag while the spring-herring in the coastal waters of western Norway. As to fishing grounds the different fisheries are subject to variations. In this respect the fat-herring fishery is the most variable. Reports from earlier days mention, however, very important fisheries of large-herring in the coastal waters of northern Norway. In the sixties and seventies of the last century this fishery was of great importance. During the period when it lasted it was very regular until about 1873 when it ceased, and since that time it has been of little importance. The spring-herring fishery is based on enormous shoals of herrings which approach the coast in order to spawn on the banks during the winter and spring months, while the large-herring fishery is based on mature herrings approaching the coast on migrations in search of food or *en route* for the spawning grounds. As has been explained in

chapter IV, also the fat-herring fishery is based on herring approaching the coast from the open ocean, but besides coastal herring play an essential part.

In the previous two chapters a statistical analysis has been made of the stocks of the fat, the large and the spring-herring in the coastal waters of Norway. The task before us is now to give a picture of the life history of the herring. In the first instance comes the study of the migrations, a problem that we will try to attack by a comparison between the growth of the fat-herring on one side and that of the large and spring-herring on the other. Before commencing this study it is necessary, however, to give a short survey of the hydrographical conditions in the waters where the herring migrate as well as a survey of the results obtained by earlier investigations on this subject.

Hydrographical conditions.

The water masses in which the Norwegian herring spend their life, originate in three different areas of the sea. There are water masses of Atlantic, Baltic and Arctic origin. The herring spawn in the coastal waters where also the young herring develop. At an age of two, three or four years — different for the various coastal districts — the young herring leave these waters and migrate into the open sea. The hydrographical conditions of the coastal waters are largely affected by the water masses carried by the Baltic Current from the Baltic through the Skagerak and along the entire coast of Norway to Murman. Consequently low salinity ($< 35\,^0/_{00}$) characterizes the coastal waters. The temperature at about 50 m. depth increases as far north as about 62° and from that latitude it decreases northwards (Helland-Hansen and Nansen 1909). In chapter III we have given a diagram which shows the yearly variation of the surface temperature in a southern and a northern locality of the coast. Contrary to the temperature, the salinity is increasing with northern latitude owing to the steadily increasing mixture with Atlantic water masses.

When the young herring migrate from the coastal waters into the open ocean, they meet quite different hydrographical conditions. The water masses of the Norwegian Sea are known from Helland-Hansen and Nansen's investigations (1909) and we reproduce a chart (Fig. 27) which shows the circulation. It will be seen that Atlantic water masses enter the Norwegian Sea between the Faroe and Shetland Islands and continue as the Norwegian-Atlantic Current northwards along the Norwegian coast, outside and below the coastal waters. About west of Troms this current divides into two branches, one of which continues northwards to Spitsbergen, while the other one turns eastwards and carries Atlantic water masses into the Barents Sea. Wherever Atlantic water penetrates it comes into contact with water masses of other origin. Thus, along the Norwegian coast it touches Baltic water and it is actually the mixture of these water masses besides fresh water from the Norwegian rivers which forms the Norwegian coastal waters. In other areas the Atlantic water comes into contact with Arctic water, in the border layers of which various phenomena of convergence occur, and we find here areas with mixed water the great biological importance of which is well known (see Hjort and Ruud 1929 and Ruud 1932). According to Helland-Hansen and Nansen the Atlantic water masses do not go deeper than about 500 m. The bottom water of the Norwegian Sea is of quite different character and origin, but this water has no greater interest to the problem concerning the life history of the Norwegian herring.

Historical remarks.

The first systematic investigations of the Norwegian herring were made in the sixties and seventies of the last century by the Norwegian investigators Axel Boeck and G. O. Sars. These investigations resulted in the important observation that the fat-herring are young and immature while the large-herring and the spring-herring are mature fish. It was also discovered that the immigration to the coastal waters has two purposes. When the spring-herring migrate to the coast in large shoals the purpose is to spawn on the banks, while the immigration of the large-herring and the fat-herring is typical food migrations.

A very important field for investigations is the study of the distribution and migration of the herring in that period of the year in which they keep away from the coastal waters. Sars brought forward the hypothesis that the herring migrate separately or in small shoals in the upper layers of the open sea during the time between the immigrations to the coastal waters. This hypothesis has on the whole been confirmed by later investigations, partly by fishing experiments and partly by more occasional observations of herring shoals in the ocean.

As regards the stock of fat-herring in the northern coastal waters, already Boeck came to the conclusion that it consisted of two contingents. He mentions that immigration of fat-herring from the ocean takes place, while other herring are living in the coastal waters throughout the year. This has later been confirmed by measurements made by Hjort (1895). Hjort says: "The fat-herring consist both of fjord herring and of oceanic herring, varying with time. Frequently the various size groups stray separately, at other times shoals are found containing all sizes. The three youngest year-classes thus originate in the fjords, while the older ones have migrated from the open sea."[1]) This has further been confirmed by Lea's investigations (1929) which we have mentioned above. We have in chapter IV described how this immigration of oceanic herring takes place, and we have also proved that the latter herring are greater and faster growing than the coastal herring.

New light has been thrown on these various problems when the method for age determination was discovered. Even the first investigations (Hjort 1908

[1]) Translated from Norwegian.

Fig. 27. The Currents of the Norwegian Sea. From Helland-Hansen and Nansen 1909.

and 1914, Dahl 1907 and Broch 1908) hinted at the possibility that herring from various localities grow at different rate. The question thus arose whether is was possible to characterize the herring of different localities by their growth and in that way to get a means for attacking the important problem concerning the distribution and migrations of the herring. Accordingly the work was chiefly concentrated on examining more closely the methods for the determination of the age and growth of the herring (Hjort and Lea 1910 and 1911). These investigations resulted also in a preliminary description of the life history of the Norwegian herring. Hjort (1914) describes it as follows: "The young fry are carried northward along the coast by the current. They spread as if sown all along the extensive range of coast, and everywhere some small fish develop, beyond doubt mostly in the northern waters. In the autumn, when these small fry are 8—10 cm. long, and $^2/_3$ year old, or in winter, at the age of about one year, when they are called "musse" or "kril", they begin to make their appearance in the seines. Next spring they begin to grow again, in May, and soon become "bladsild" (12—15 cm.). Most of them remain during the following winter at this length, some, however, grow faster. During their third year, some at least of the year-classes begin to associate themselves with the fat herring, and for the next two or three years, according to locality, they belong to the fat shoals.

At an age of 4, 5 or 6 years they separate from

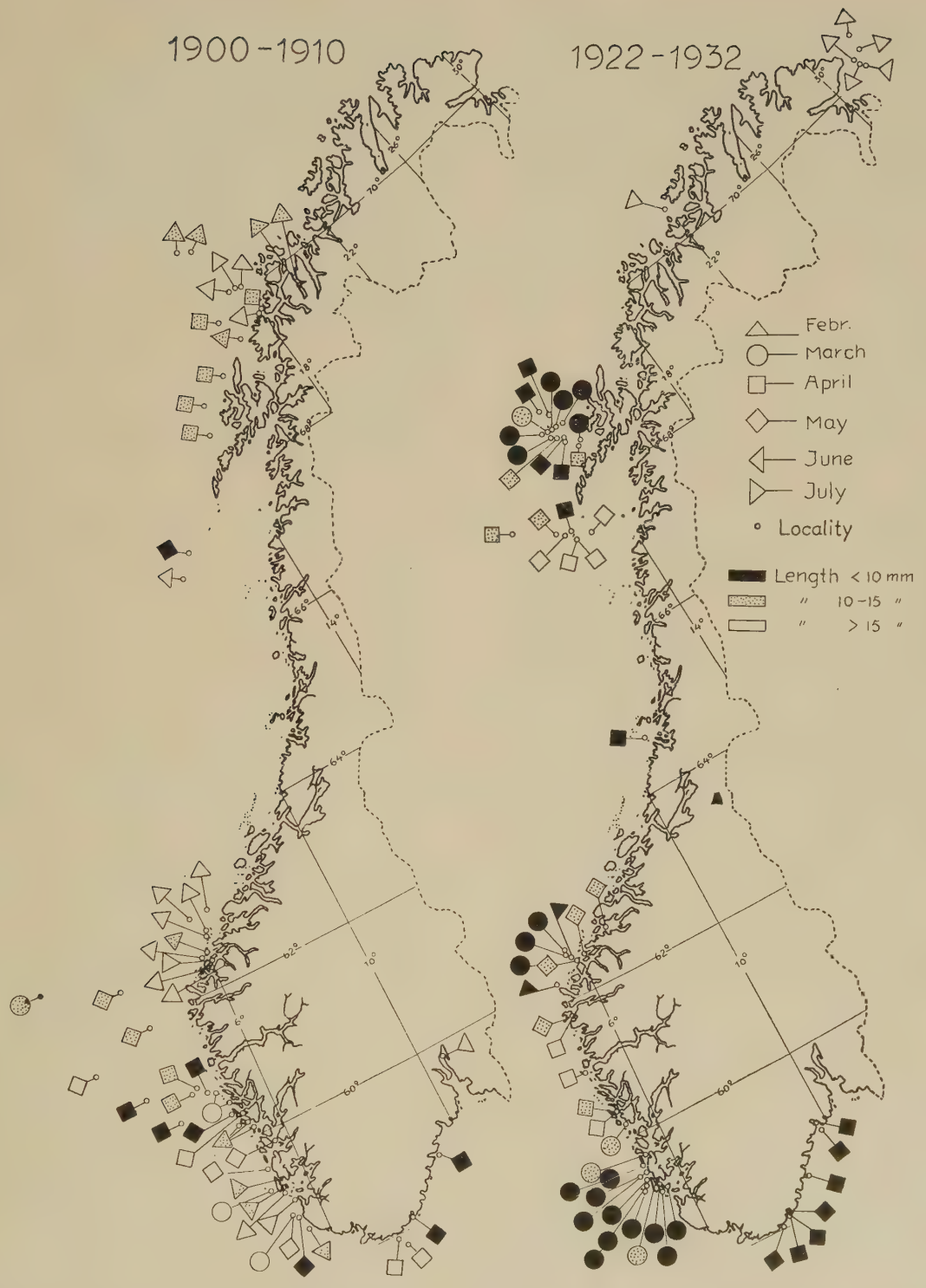

Fig. 28. o Localities on the Norwegian coast where herring larvae have been captured. ■ length < 10 mm. (recently hatched), ▣ length 10—15 mm., □ length > 15 mm. From Runnstrøm 1933, 1.

these, in the autumn, when the genital organs are beginning to develop; they are then "large" and in the following spring become "spring herring". At this time they undertake migrations of greater or lesser extent, moving southwards along the coast, in a direction contrary to that in which they as young fish were passively carried by the current."

It will be noticed that this preliminary description is based on the assumption that the total of fat-herring in northern Norway become southern Norwegian large and spring-herring and, moreover, that the

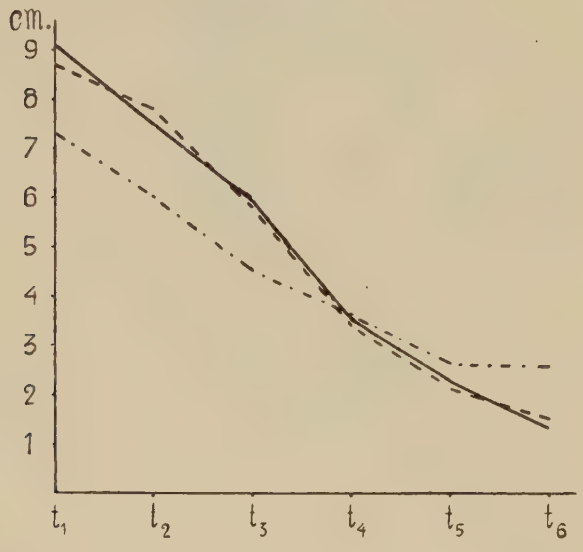

Fig. 29. Graphic representation of the mean yearly increments in length of the A-type of the year-class 1904. ———— spring-herring, — — — — large-herring, —·—·—·— fat-herring.

migration from the fat-herring shoals to the shoals of large and spring-herring takes place during some few winter months. It was in the first place based on the investigations by Lea of the migration of "marked" herrings and on the fact that the year-class 1904 emigrated from the fat-herring shoals in the autumn of 1909 and immigrated into the spring-herring shoals in the spring of 1910. Lea who had the opportunity to go further into these matters, came to the conclusion, however, that the migration from the fat-herring shoals to the spring-herring shoals has to last much longer. New investigations brought him to the view that the herring in this migration-stage were inhabitants of the open sea for about 2—3 years. He called this stage the "oceanic". In chapter IV we have shown that the fat-herring stock during the autumn of 1915 was augmented with large, fast-growing fat-herring. Undoubtedly this immigration originated in the ocean and represented the "oceanic stage".

The knowledge, however, of the life history of the Norwegian herring is strongly enlarged owing to experience obtained by charting the occurrence of newly hatched herring larvae (Runnstrøm 1933, 1). These investigations have shown that the spawning of the herring takes place in more northern localities than previously supposed. We reproduce a chart (Fig. 28) of the localities where newly hatched herring larvae have been found. It is evident from this that the spawning of the Norwegian herring is not limited to the localities where spring-herring fishery takes place, but is distributed along the entire coast as far north as Lofoten and Vesterålen. Runnstrøm says that it seems as if the annual spawning migration to the coastal waters at Vesterålen is unfailing. It is obvious that these new experiences are of some consequence to our understanding of the life history of the Norwegian herring.

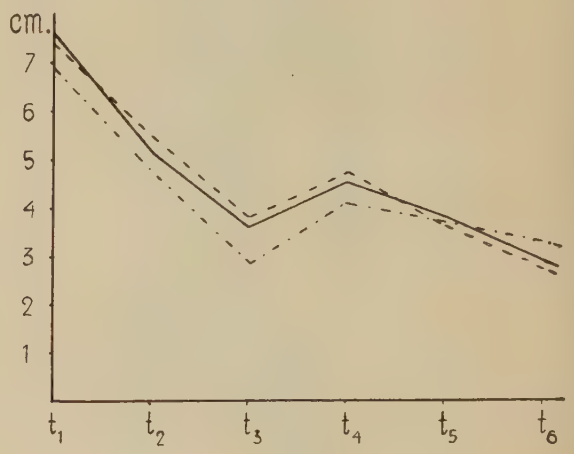

Fig. 30. Graphic representation of the mean yearly increments in length of the C-type of the year-class 1904, ———— spring-herring, — — — — large-herring, —·—·—·— fat-herring.

Comparison between the growth of the fat-herring and that of the large and spring-herring.

In chapter III we have made a comparison (Fig. 4) between the growth of the fat-herring from northern Norway and of the spring-herring from southern Norway. It was proved in this way that the spring-herring grow much faster than the fat-herring. This shows that the fat-herring in the northern waters can at a later age form only a portion of the southern spring-herring shoals, if they join these shoals at all. The other portion of the spring-herring shoals must be recruited from other waters. One has tried to calculate how great that portion of the spring-herring stock may be which is recruited from the northern fat-herring shoals (Hjort and Lea 1911). These calculations were, however, based on the assumption that the total of "marked" herring (C-type) of the fat-herring have to be found in the spring-herring shoals as "marked" herrings, viz. that the C-type of the fat-herring is identical with the C-type of the spring-herring. It was assumed that the whole stock

of northern fat-herring joins the southern shoals. A comparison between the growth of the fat-herring and that of the spring-herring will prove, however, that this assumption is not correct.

It will be seen from Fig. 29 that the curves for the length increments of the A-type of the year-class 1904 as large-herring and as spring-herring are nearly identical, a fact which has been mentioned in chapter V. Moreover, it will be noticed that the fat-herring (the A-type) has lesser length increments than the large and spring-herring. This fact proves that the A-type of the fat-herring in northern coastal waters is not identical with the A-type of the southern large and spring-herring. Fig. 30 shows that the same fact applies to the C-type. In the first four years the mean difference between the yearly increments is equal to

Table 50. Mean values (m) in cm. of t_1 and t_2 for the year-class 1904 as fat, large and spring-herring. μ stands for the standard deviation of the mean and N for the number of individuals examined.

Growth-type	Stage	t_1		t_2		N
		m	μ	m	μ	
A	Fat	7.3	0.111	6.1	0.158	92
	Large.....	8.7	0.052	7.7	0.057	527
	Spring.....	9.1	0.037	7.5	0.012	875
C	Fat	6.9	0.043	4.9	0.054	284
	Large.....	7.4	0.060	5.5	0.057	291
	Spring.....	7.6	0.045	5.2	0.041	566

0.5—1.0 cm. Table 50 shows the mean length increments in the first two years of life (t_1 and t_2) and the standard deviation of these means for the fat, the large and the spring-herring. A comparison between the growth of the A-type as fat-herring and as large-herring gives for t_1 the difference 1.4 cm. and for t_2 the difference 1.6 cm. Measured with their standard deviation these differences are equal to 11.4 and 9.5 respectively. A comparison between the growth of the C-type as fat-herring and as large-herring gives for t_1, the difference 0.5 cm. and for t_2 the difference 0.6 cm. Measured with their standard deviations these differences are equal to 6.8 and 7.6. Consequently, there is a very small probability that these differences would be eliminated or reversed if new observation data were collected under the same conditions. This result is verified by the fact that all mean values of t_1 and t_2 — each growth-type considered separately — are greater for the large-herring than for the fat-herring. There is no reason, however, for a detailed discussion and we will confine ourselves in referring to chapter IV and V.

These facts show that the C-type of the fat-herring is not identical with the C-type of the large and spring-herring. The very same holds good for the A-type. Accordingly, the growth-mark which characterizes the C-type ($t_3 < t_4$) cannot be considered as a mark by means of which we can follow the herring on their migrations. If the C-type is found in the fat-herring shoals one autumn and in the spring-herring shoals for the first time the following spring, this fact cannot be taken as a proof that migration has taken place from the fat-herring shoals to the spring-herring shoals during the intermediate time.

The following investigation of the year-class 1918 gives the very same result. It will be seen from Table 51 that the growth of the A-type as large and

Table 51. Mean values in cm. of t_1, t_2 and t_3 for the growth-type A of the year-class 1918.

	Year	t_1	t_2	t_3
Fat-herring	1920	9.1	5.9	4.8
Large-herring ...	1925	11.0	6.7	5.6
Spring-herring ...	—	10.5	6.8	5.6

Table 52. Mean values in cm. of t_1, t_2 and t_3 for the growth-type B of the year-class 1918.

	Year	t_1	t_2	t_3
Fat-herring.....	1920	8.3	4.8	5.5
Large-herring ...	1925	10.2	5.5	6.2
Spring-herring ...	1925	10.0	5.4	6.3

spring-herring is the same, while there is an essential difference between the growth of the fat-herring on one side and that of the large and spring-herring on the other. This also applies to the B-type (Table 52). If we compare the growth of the fat-herring and that of the spring-herring, we find for the A-type the following differences: 1.4 cm. for t_1 and 0.9 cm. for t_2. Measured with their standard deviations these differences are equal to 12.3 and 10.9 respectively. If we examine the B-type in the same way, we find for t_1 the difference 1.7 cm. and for t_2 the difference 0.6 cm. which measured with their standard deviations are equal to 12.6 and 6.8 respectively. Accordingly, the probability is very small that these differences would be eliminated or reversed if new observations were collected under the same conditions.

From these experiences the question arises whether the northern fat-herring join the southern large and spring-herring shoals at all. According to our investigations the proof of such migrations taking place, viz. the observation of "marked" herring in the fat-herring shoals one autumn and in the spring-herring shoals the next spring, does not hold good because the "marked" herring of the large and spring-herring grow essentially faster than those of the fat-herring. The erroneous conclusion is due to the fact that at that time "marked" herring had only been found in a single year-class (1904). It was thus natural to consider the growth-mark ($t_3 < t_4$) as an abnormity in the growth of some herring of the year-class 1904 and that this mark could, therefore, be taken as a characteristic of the individuals of this year-class which had spent their third year of life (the year 1906) in the coastal waters of northern Norway. The bare experience that "marked" herring are found in all year-classes of the Norwegian herring, forms a sufficient basis for the conclusion that these ideas are not striking. In what follows we are going to give an account of the conclusions which we have arrived at.

It will be seen from Table 50 that the mean increment in the first year of life (t_1) for the A-type of the fat-herring is nearly the same as that for the C-type of the large and spring-herring. Fig. 31 shows, moreover, that the frequency curves of t_1 for the A-type of the fat-herring and that for the C-type of the large-herring are approximately identical and that both these curves are strongly displaced in relation to the corresponding curves for the C-type of the fat-herring and for the A-type of the large-herring. The increment in the first year of life (t_1) for the A-type of the fat-herring and that for the C-type of the large-herring have, thus, not only nearly the same mean values, but also the very same frequency distributions. The same good agreement also appears

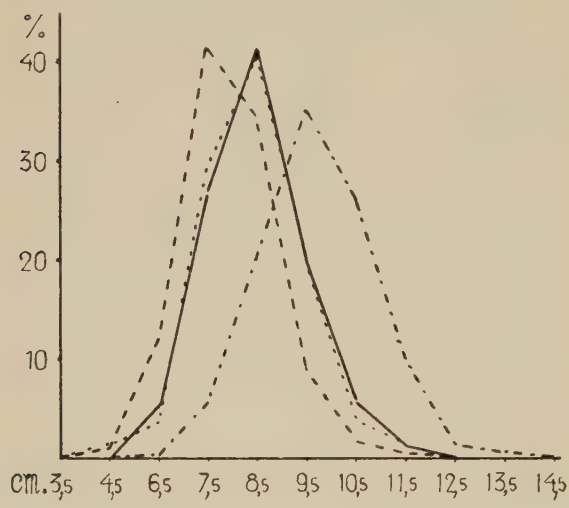

Fig. 31. Frequency curves for t_1 of the year-class 1904. ———— C-type large-herring ..... A-type fat-herring —·—·—·— A-type large-herring — — — — C-type fat-herring.

when we compare the fat-herring and the spring-herring, but we see no reason for going further into these matters.

The following investigation of the year-class 1918 will throw much light upon these problems. It will be seen from Table 53 that the mean yearly increments in the first three years of life for the A-type of the fat-herring and those for the C-type of the large and spring-herring are approximately equal. This fact shows that the A-type of the fat-herring and the C-type of the large and spring-herring have spent their first three years of life in waters which present the very same conditions for growth, and it indicates that these groups originate in the very same area of the coastal waters. If we study the frequency distribution of one of these quantities, t_2 for example, it will be seen from Fig. 32 that there is the best agreement between the A-type of the fat-herring and the C-type of the spring-herring.

This agreement of growth cannot, however, be considered as a proof — without other statements — that the C-type of the year-class 1918 as large and spring-herring in 1925 is identical with the A-type

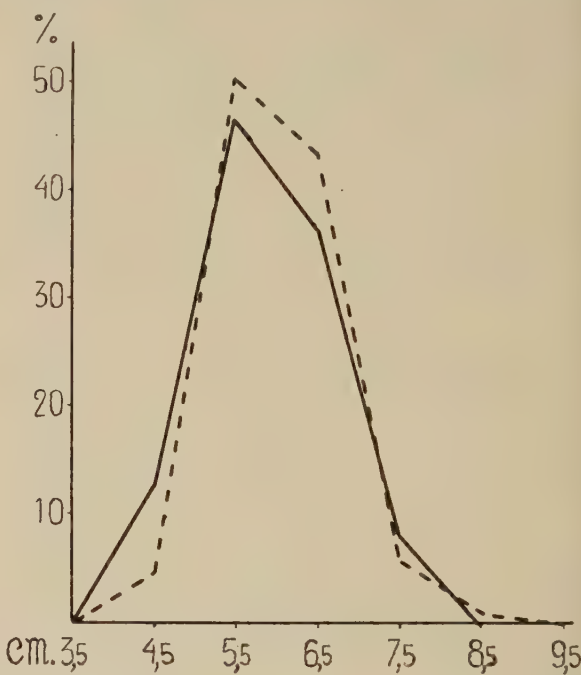

Fig. 32. Frequency curves for t_2 of the year-class 1918. — — — — A-type fat-herring, ———— C-type spring and large-herring.

of the same year-class as fat herring in the autumn of 1920. It may be that two different areas of the Norwegian coastal waters produce the same growth-rate, i. e., present the same growth conditions. But, at any rate, this agreement shows that if any migration takes place from the fat-herring shoals in the northern waters to the large and spring-herring shoals in the southern waters, it is the A-type of the fat-herring which undertakes this migration.

The year-class 1918 of the fat-herring was $2^1/_2$ years of age in the autumn of 1920. The facts mentioned above can therefore be explained in the following way. The individuals of the year-class 1918, or a portion of them, which in the autumn of 1920 belonged to the A-type of the fat-herring, migrated in the following winter from the coastal waters to the ocean. That such an emigration has actually taken place is suggested by the fact that the A-type of the 1918 year-class of the fat-herring in 1920 amounted to 85 % while the next autumn (1921) to only 48 % of the total number of individuals of this year-class.

Table 53. Mean values in cm. of t_1, t_2 and t_3 for the year-class 1918.

	Growth-type	t_1	t_2	t_3
Fat-herring	A	9.1	5.9	4.8
Large-herring ...	C	9.5	5.9	4.7
Spring-herring ...	C	9.5	5.8	4.7

Moreover, the year-class 1918 amounted to a very large percentage of the fat-herring in the autumn of 1920, while in the autumn of 1921 to a very small percentage. These facts indicate that a number of individuals of the year-class 1918 emigrated from the fat-herring shoals between the autumn of 1920 to the autumn of 1921.

The migration from the northern coastal waters to the ocean is directed from waters of less favourable to waters of more favourable conditions for growth, and it is obvious that the growth of the migrated herring must be characterized by this migration. It is also evident that the individuals of the A-type ($2^1/_2$ years old) which emigrated, had to take the character of the C-type, viz. characterized by smaller length increment in the third year (last year in the coastal waters) than in the fourth year (first year in the ocean). Of course we are quite aware of the fact that this cannot be taken as a proof. But we cannot see that any other explanation is possible. We are of the opinion, moreover, that a study of a larger material collected for this particular purpose, and treated on the lines we have tried to draw up, will result in a verification of our hypothesis.

Description of the life history of the Norwegian herring.

The task before us now is to give a short description of the life history of the Norwegian herring. This description must, however, have to be very schematic, because we have not been able to elucidate fully the various questions associated with this problem. The opinion at which we have arrived of the life history of the herring differs from the preliminar description by Hjort (1914) therein that the growth definitely indicates the existence of two Norwegian herring stocks, a southern and a northern one. This opinion is based on the fact that there is only a portion of the northern fat-herring stock, viz. the individuals of the A-type or only a portion of them, which later join the southern large and spring-herring shoals. This agrees well with the results arrived at by the investigations of the spawning grounds. As pointed out by Runnstrøm (1933, 1) the chart showing the occurrence of newly hatched herring larvae, reproduced in Fig. 28, is not complete. But still we must be entitled to suppose that there are, broadly speaking, two separate large areas for the spawning of the herring. The southern area extends from Møre southwards and is thus identical with the area within which the spring-herring fishery takes place. The northern area embraces the coastal banks outside Vesterålen and Lofoten.

Hjort's description is, on the whole, correct as far as the southern Norwegian herring stock is concerned. The spawning takes place along the west coast northwards to Møre. The fry drift northwards with the coastal current and develop in the fjords and the coastal waters. At the age of two or three years the young herring leave the coastal waters and take up an oceanic existence. This oceanic stage seems to last 2—3 years, and at the age of 4, 5, 6 or 7 years the herring return to the coast as large and spring-herring. Occasionally oceanic herring of the southern stock approach the coast as fat-herring. In the autumn of 1915 such an immigration to the northern waters occurred, and it is reasonable to suppose that the fat-herring fishery from Trøndelag southwards, which is very variable, is mainly based on immigration of oceanic herring of the southern stock.

The northern Norwegian herring spawn, according to present experience, on the banks outside Vesterålen and Lofoten. The fry drift northwards and eastwards with the current and develop in the coastal waters of Troms and Finmark and possibly also in the Barents Sea. Later on these herring form an essential part of the northern fat-herring shoals (the growth-types B and C, and partly the A-type). The age at which the young herring leave the coastal waters seems to be very variable. In some years fat-herrings of $7^1/_2$ years of age are found (1909), while in other years the oldest fat-herring are but $3^1/_2$ years of age (1915). For the present time the life cycle of the northern herring stock must be supposed to be fairly parallel to that of the southern herring stock. At a certain age the herring leave the coastal waters and migrate into the open sea where the development of the sexual organs takes place, and later on they return to the coast as northern spring-herring and large-herring. There is, however, no hope of completely understanding these facts until the herring of the Barents Sea have been more closely investigated. But first of all it is of importance to procure and examine samples of the herring which spawn on the banks at Vesterålen.

Fig. 33 shows the utmost limits of distribution of the youngest stages of cod (Hjort 1914). It will be seen that a drift towards the open sea takes place of larvae which originate from spawning in the coastal waters. Whether a similar drift of herring larvae occurs cannot be said definitely, but it is very probable. If this is the real fact, some larvae come under more favourable growth conditions than those remaining in the fjords and the coastal waters. Possibly the larvae from the southern spawning grounds which are drifting into the ocean, become herring of the A-type of the southern stock, while the larvae which remain in the coastal waters, become herring of the B-type and C-type. If this is the case, the growth-mark is due to migration from the coastal waters to the open sea, as regards the B-type ($t_2 < t_3$) from the southern waters and as regards the C-type ($t_3 < t_4$) from the northern waters. Further, the drifting towards the ocean may explain the appearance of large, fast-growing herring in the Barents Sea (see chapter IV). Our material, however, can give no proof for the correctness of these ideas.

It would, of course, be of great interest to state — on one side — how great a portion of the southern spring-herring stock is recruited from the northern fat-herring shoals, and — on the other side — how great a portion of the northern fat-herring stock

Fig. 33. Extreme limits of distribution of the youngest stages of cod.
I. Newly spawned eggs, II. Larvae and small fry, June, III. Young fish, Aug.—September 1900.
From Hjort 1914.

becomes southern spring-herring. The material at hand is not sufficiently large to form a basis of quite reliable investigations. However, if we take it for granted that only the C-type of the spring-herring is recruited from the fat-herring stock, and moreover, if we take the 1904 year-class as a representative of the spring-herring, about 35 % are found to be recruited from the northern fat-herring shoals (see Table 44, chapter V). The A-type and the B-type of the spring-herring must, accordingly, be recruited from other fat-herring shoals. These two growth-types obviously originate in different areas, but none of them originate in the northern coastal areas. When speaking of northern fat-herring in this connection, we include only the coastal contingent and not the oceanic.

To calculate how great a portion of the northern fat-herring stock emigrates and joins the southern spring-herring shoals is very difficult. From our previous investigations is appears that only a certain portion of the A-type of the fat-herring emigrates and joins the spring-herring shoals, but as to how great a portion, we have no idea. Assuming, however, that the total of northern fat-herring of the A-type become southern spring-herring, an idea can be obtained of the maximal migration from the northern fat-herring shoals to the southern spring-herring shoals. If we take the 1913 year-class in the autumn of 1915 as a representative of the fat-herring, we find that about 60 % of the fat-herring become southern spring-herring. This figure is, however, not quite reliable. Moreover, it is too high, because not the total of fat-herring of the A-type becomes southern spring-herring. Thus, the individuals of the A-type of the 1904 year-class as fat-herring in the autumn of 1909, become, probably, not southern spring-herring at all.

However, no definite proof has been given that migrations take place from the northern fat-herring shoals to the southern spring-herring and large-herring shoals. But it is very probable that this is the real fact. The only statement which can be made on the

basis of our growth investigations is that, if any migration takes place, it is the herrings of the A-type of the fat-herring which undertake these migrations. But whatever the answer may be which posterity will give to these questions, it is evident that a very considerable portion of the northern fat-herring stock never joins the southern large and spring-herring shoals. The spawning grounds of the northern stock must, for the present time, be supposed to be the newly discovered grounds off Vesterålen and Lofoten, but spawning takes probably place also further north and outside the Helgeland coast.

Curiously enough no fishery for spawning herring takes place in the northern Norway. Possibly this is due to the circumstance that the grounds lie far out at sea, and that the fishermen therefore are not aware of the immigration of herring. It is more probable, though, that the spawning is more widely distributed and that the herring never arrive in such large masses as in the important spring-herring localities in the southern Norway. It should also be remembered that according to our present experience, the stock of spawning herring in northern Norway must be supposed to be small as compared with the southern spring-herring stock.

Before finishing we would like to emphasise that this description of the life history of the Norwegian herring only endeavours to reconcile the understanding of the various problems with present experience. We will, however, mention some other facts which point in the same direction as our growth studies. JOHANSEN (1919) has found some difference between some anthropometrical characters of the northern and the southern Norwegian herring. The examinations by RUNNSTRØM (1933, 2) of the number of vertebrae, moreover, point in the direction of the existence of two Norwegian herring stocks. RUNNSTRØM says: "Es ist jedoch eine Tendenz dafür vorhanden, dass die im nördlichen Norwegen gewachsenen Heringe nördlichere Laichplätze aufsuchen, als die im südlichen Norwegen aufgewachsenen Heringe." We fully understand, however, that a great number of new facts must have to be produced before there is any hope of understanding the entire life cycle of the Norwegian herring.

SUMMARY

1. Some statistical methods have been discussed in chapter I. First, an account has been given of the representative method of investigation in fishery research. Particularly we have emphasised that it is necessary to ascertain empirically whether a single sample can represent the entire shoal of fish from which it has been taken. We have given an example of such an investigation. Thus, Table 1 shows that the age-composition of 4 samples, collected in the same locality and at about the same time, agree very well, and Table 2 shows that the mean growth of a certain growth-type (A) is also identical in these 4 samples.

Next, we have discussed shortly the employment of frequency functions, particularly the exponential frequency function, in biological investigations. In this connection we have dealt with the use of the standard deviation as a measure of the distribution of statistical series.

2. For obvious reasons, it is of the greatest importance for the study of the growth of fish to ascertain what relation there is between the growth of the fish and that of its scales. The hypothesis that this growth-relation is linear has been discussed in many papers of recent years. Many investigators have advocated the opinion that this problem must be studied by investigating the correlation between the length of the fish and a particular linear scale-dimension. We have tried to prove that this method cannot lead to correct conclusions (Chapter II).

Our investigation of this problem is based on the following considerations: If there is a proportional relation between the growth of the fish and that of its scales, the calculated length of an individual at different ages (l_1, l_2, l_3 etc.) must be independent of the age at which the examination and calculations are made. By studying the mean calculated growth of the same year-class (1904) at different ages we have got an empirical proof that the hypothesis in question is correct (Tables 8 and 9). From this we have concluded that the herring and its scales grow in proportional ratio and, consequently, that the growth of each single herring can be calculated by means of its scales.

3. Even the first investigations of the growth of the herring proved the existence of different growth-types. Experience shows, moreover, that herring caught in the coastal waters of southern Norway grow essentially faster than herring caught in northern waters (Fig. 4). Our task has been, *inter alia*, to find the causes of this growth-difference. For this purpose we have collected a material of herring in the second year of life in a southern and in a northern area of the coastal waters during the summer 1933. It appeared (Fig. 5, chapter III) that the growth season in the southern area lasts about twice as long as that in the northern. Consequently the total increment in length during the season was much greater in the first than in the latter area.

A very interesting observation was made by LEA (1911). He found that some individuals of the year-class 1904 were characterized by larger length increment in the 4th than in the 3rd year of life. These individuals he called "marked" herring, and he was

of the opinion that their growth was abnormal. We have now observed that such "marked" individuals occur in all year-classes of the Norwegian herring and, in addition to these, herring whose growth is characterized by larger length increment in the 3rd than in the second year of life. Thus, there are found three growth-types which we have denoted A, B and C (see Fig. 7, chapter III). The A-type is characterized by decreasing yearly increments with increasing age, the B-type by larger increment in the 3rd than in the second year and the C-type by larger increment in the 4th than in the 3rd year of life. The herring of the B-type and the C-type amount to a considerable portion of the stock. Tables 10 and 11 give some examples of the quantitative ratio between the different growth-types.

4. In chapter IV we have made an investigation of the growth of the fat-herring. The composition of the fat-herring stock in the coastal waters of northern Norway is very complicated. Thus, a distinction can be made between a coastal contingent and an oceanic contingent. It is a well-known fact that the fat-herring fishery is based partly on immigration of oceanic herring. We have proved that there are great divergencies between the two contingents of the fat-herring. Thus, the oceanic contingent is composed of older individuals than the coastal contingent (Table 21 and 22), and moreover, the oceanic herring are larger and faster growing than the coastal herring (Fig. 12).

Is has also been proved that the different growth-types of the coastal herring grow at different rate. Thus, the A-type has larger length increments in the first years of life than the two other growth-types (B and C). This fact has been taken as an evidence that the A-type originates in areas which present more favourable growth-conditions than the areas in which the two other growth-types originate.

5. A corresponding investigation of the growth of the large-herring and the spring-herring has been made in chapter V. As regards these herring it has been proved also that the different growth-types grow at different rate. Particularly, the A-type has greater length increments in the first years of life than the two other growth-types (B and C) (see f. inst. Fig. 16). No growth-divergencies can be proved between the large-herring and the spring-herring.

The fact that the B-type and the C-type have lesser length increments in the first years of life than the A-type must be taken as an evidence that the latter growth-type originate in more southern areas of the coastal waters than the growth-types B and C.

6. We have in chapter VI tried to attack the important problem of the migrations of the Norwegian herring by comparing the growth of the fat-herring on one side and that of the large and spring-herring on the other. The first result arrived at by this comparison, is the fact that the different growth-types (A, B and C) of the large and spring-herring considered separately grow faster than those of the fat-herring. The A-type of the fat-herring in the northern waters, however, has the very same length increments in the first years of life as the C-type of the large and spring-herring in the southern waters (see Table 53). This fact has been taken as a proof — if any migration takes place at all — that it is the A-type of the fat-herring which undertakes the migration from the fat-herring shoals to the shoals of the large and spring-herring. When fat-herring of the A-type at the age between the 3rd and 4th growth season migrate to the ocean and join the southern large-herring shoals, they come under more favourable growth-conditions and consequently become herring of the C-type.

These facts besides the new experiences as regards the spawning grounds have led to a new understanding of the life history of the Norwegian herring. We are now of the opinion that there are two Norwegian herring stocks, a southern and a northern one. The southern stock spawns on the coastal grounds where now the spring-herring fishery takes place. The northern stock spawns on more northern grounds, particularly — according to the present experience — on the banks off Vesterålen and Lofoten (see Fig. 28).

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Erratum.

The author asks to have the following correction made, but unfortunately the page has already been printed.

Page 8, Column 2, line 1—3: should read:

»As regards the importance of this coefficient we will confine ourselves to a reference to Tschuprow (1925)[1]. The main object is that it cannot . . . . . .«

[1]) Tschuprow, 1925. Grundbegriffe und Grundprobleme der Korrelationstheorie, Leipzig 1925.

IV

OCEANOGRAPHIC CONDITIONS AT CERTAIN NORWEGIAN FISHING GROUNDS

BY

JENS EGGVIN, Bergen

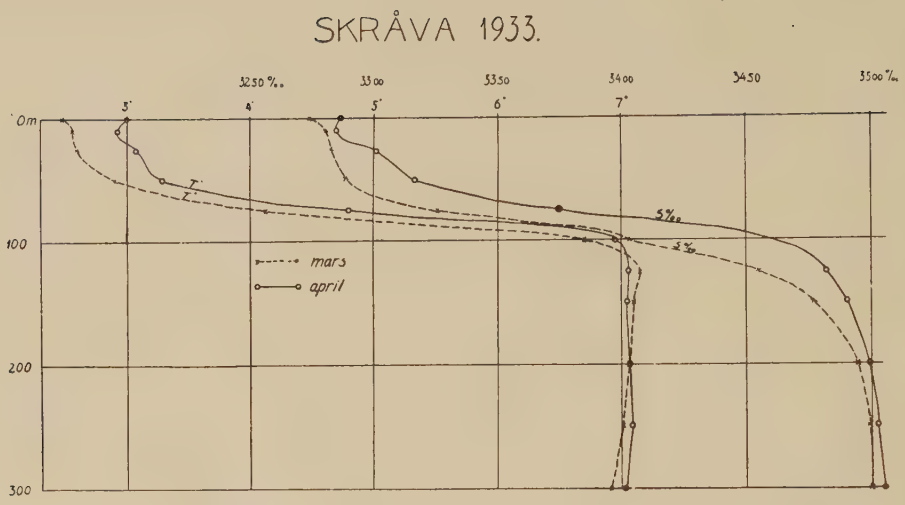

Fig. 1. Temperature and salinity at Skraava in March and April, 1933.

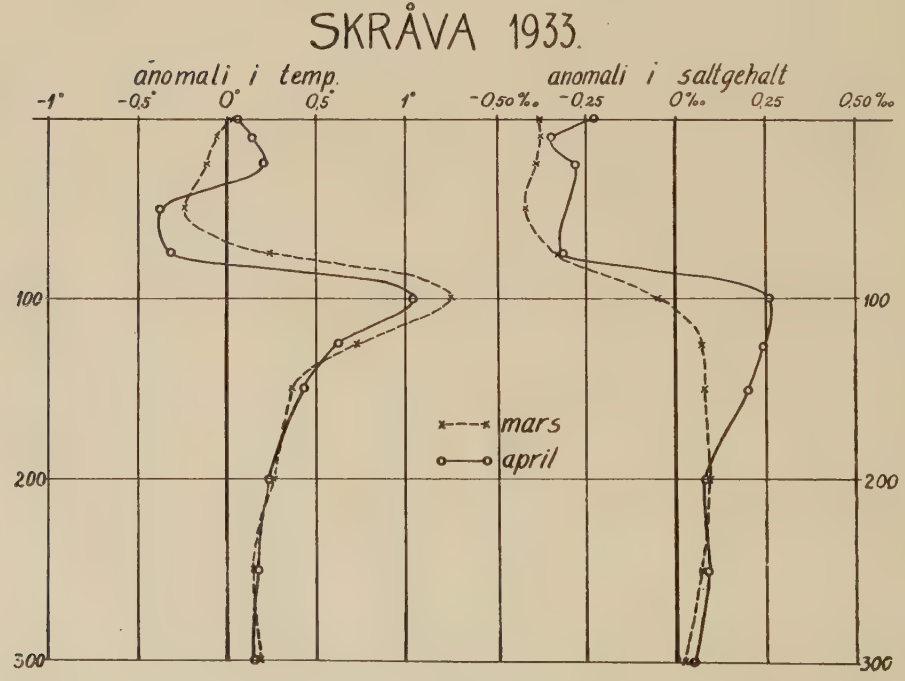

Fig. 2. Anomalies of temperature and salinity at Skraava in March and April, 1933.

The Vestfjord, the scene of the well-known Lofoten "skrei"-fishery, like other Norwegian fjords, is a "threshold-fjord". Between Værøy and Røst on the one side, and Bodø, on the other side of this fjord, a wide submerged ridge connects the two sides, the saddle depth being 227 m. Inside this, the fjord is considerably deeper, reaching at certain places a depth of more than 600 m. The great importance of this "threshold" is that it generally determines the character of the bottom water in the fjord. From the ridge, 77 nautical miles W.S.W. of Røst, the "Trænjupet" cuts deep down in the shelf (as deep as 488 m.) and continues as a deep sea canal with decreasing depths right along to the "threshold". Relatively cold water, consisting of Atlantic water, cooled by the deepsea water of the Norwegian sea, penetrates through the outer part of this deep. The stations 55 and 80, made by the "Johan Hjort" on the 4th and 10th of March, 1933, respectively, show the difference of temperature on both sides of the "threshold":

m.....	125	150	200	250	300	400
Station 55 in the "Trænjupet" 66°42′N. 10°59′E.	6.91	7.00	6.94	6.95	7.05	5.79
Station 80 inside the "threshold" 68°01′,7N. 15°16′E.	7.08	7.00	7.06	7.08	7.01	6.92

In the "Trænjupet" the temperature decreases by 1.26° from 300 to 400 m., while the corresponding drop in temperature at station 80 is 0.09° only.

Due to the depth of the "threshold", the deeper parts of the Vestfjord are filled with water of about 7° and a salinity of about 35 ‰. Generally the temperature and salinity are lower than these values.

During the Lofoten fishery in 1933 the oceanographic conditions of the Vestfjord were characterized by the high temperatures dominating in the water masses from 85 m. to the bottom, and particularly abnormally high ones at 100—150 m. depth. Further, the transition-layer between the winter-cooled, thoroughly mixed coastal water and the warmer and salter deep water below, was especially conspicuous. The transition-layer was therefore very thin. At Skraava the average thickness was 7 m. only between the temperature limits of 4.5 and 5.5° C. For comparison it may be mentioned that the corresponding figures for 1930, 1931 and 1932 were 35, 8 and 20 m. From a fishery point of view, this transition-layer is of the greatest importance, experience having proved that the skrei, during the Lofoten fishery, keep to this layer, and particularly so within the temperature limits of 4.5°—5.5° C.

To illustrate the situation, the T° curves of Fig. 1 show the average temperature at various depths 2 miles S.S.E. of Skraava for March and April, 1933. It will be noticed that the temperature reaches about 7° almost from 100 m. to the bottom, further that the winter-cooled, mixed coastal water keeps a temperature of 2.5°—4°, and that the depth-difference between the 4° and the 7° water is but small. At the outer right hand side of the figure are shown the corresponding curves for the salinity (S.‰). The mixed upper layer has a salinity of about 33 ‰, and the deep water of about 35 ‰. Further it will be noticed that the salinity is somewhat higher in April than in March, a generally acknowledged phenomenon, inasmuch as the force of the deep water increases and reaches a somewhat higher level during April.

During the Lofoten fishery the Fishery Directorate has made annual investigations in the Vestfjord since 1922. During these cruises all of which, except that of 1925, were under the direction of Mr. Sund, observations have been repeated several times during the season at various places. By forming mean values of temperature and salinity for each position, for March as well as April, for the period 1922—1932 (1925 excepted), a good foundation for comparison has been obtained in respect of determining deviations in individual years from the normal values of temperature, salinity and density.

Fig. 2 shows the anomaly between the values of Fig. 1 and the corresponding mean-values at Skraava. The minus sign indicates 1933 values below the normal.

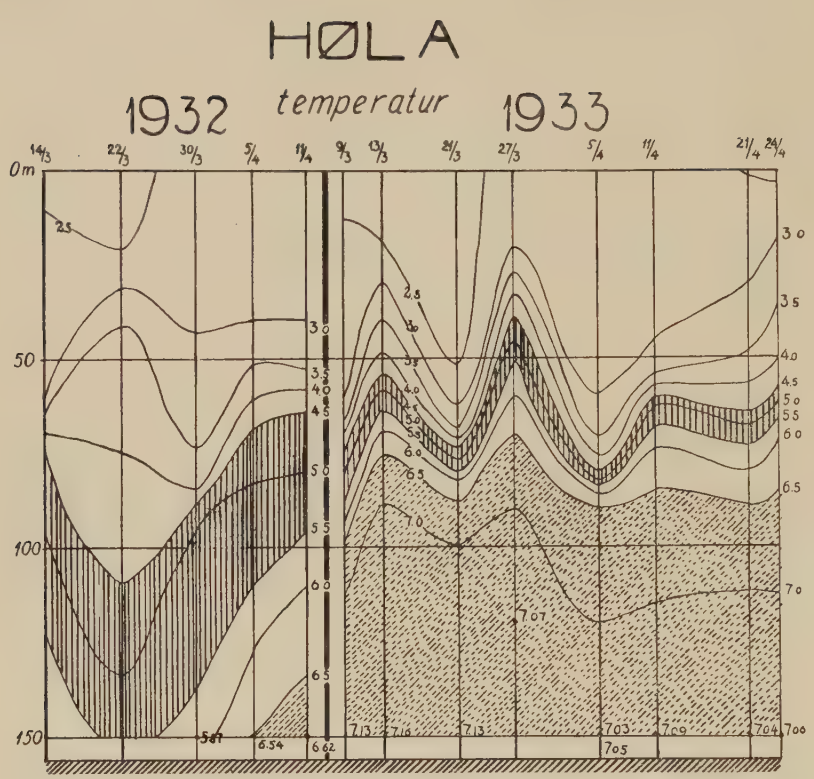

Fig. 3. Høla, the well-known fishery district of Lofoten, in March—April, 1932—33. Water with temperatures of 4.5°—5.5° C. vertically shaded, and water with a temperature higher than 6.5° shaded by dotted lines.

It will be noticed that the March temperature is slightly below the mean-value at depths from 5 to 70 m., while considerably higher from 75 m. to the bottom (300 m.). As mentioned above this is particularly evident between 85 and 150 m., with a maximal value of 1.25° above mean at 100 m. The April curve shows a similar course; the temperature is below average between 35 and 80 m., while higher at other depths. During April also the highest difference (just over 1°) is to be found at 100 m.

By comparison it appears that the average temperature between 100 m. and the bottom, during March—April, 1933, has been higher than in any other year within the period 1922—1932 (1925 excepted), a circumstance which has been noticed not only at Skraava but everywhere in the Vestfjord.

The curves at the right hand side of Fig. 2 indicate a circumstance of great practical importance, viz. that the salinity in the upper 80 m. of water has been considerably lower than the mean values during March as well as April. From about 100 m. to the bottom it was above average with the greatest positive deviation between 100 and 150 m. depth.

It is a noteworthy fact that the salinity in March has been below average from the surface and as far down as 105 m., while the temperature has been above the mean even at 70 m. already. From this it may be deduced that the high March temperature at 100 m. depth is not due merely to the fact that the Atlantic water has ascended so high, but is also due to the fact that the winter-cooling has been less than normal at this depth on account of low salinity in the upper layers in conjunction with the abnormally high air temperature during December and January.

As is the case at Skraava, the highest positive deviations from average values were determined at 100 m. at the well-known fishery district of Høla (between Skraava and Østvaagøy, see Fig. 5); here the deviations were as high as 1.75° and 1° during March and April, respectively. At that time of the year those are the highest temperatures for Høla observed at 100 m. since 1892.

The following table shows the temperatures observed at 100 m. during the Lofoten fishery of 1932 and 1933 at Høla.

Table 1.

1932...		14/3	22/3	30/3	5/4	11/4		
t° C....		5.08	4.34	5.14	5.21	5.70		
1933...	9/3	13/3	21/3	27/3	5/4	11/4	21/4	24/4
t° C....	6.61	7.05	7.00	7.10	6.64	6.94	6.92	6.82

The mean temperature of 1932 was 5.09°, while that of 1933 was 6.89°.

The temperature at 100—150 m. being abnormally high, the bottom water on the fishery grounds was also very warm at corresponding depths. This may

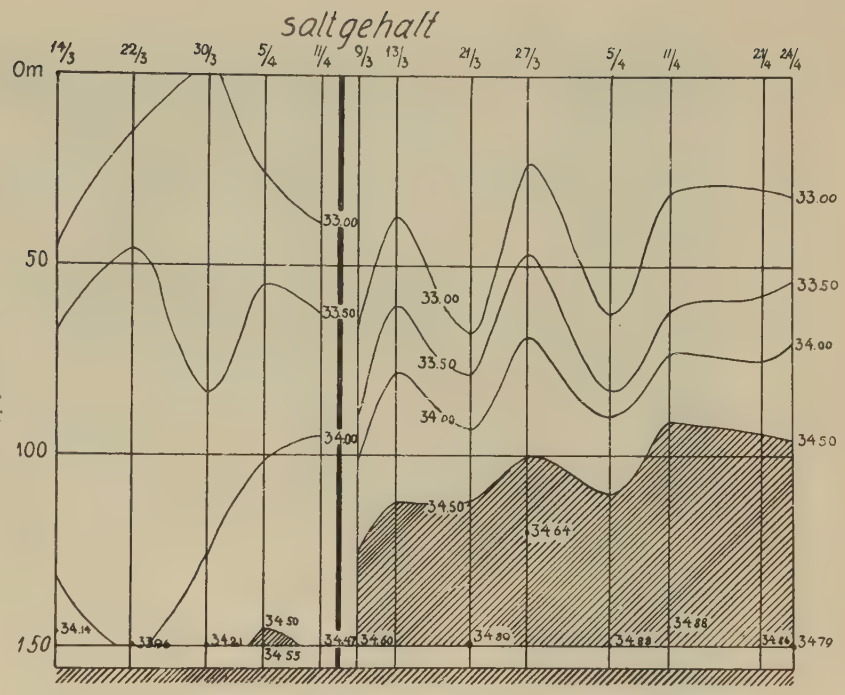

Fig. 4. Høla in March—April, 1932/33. The shading indicates a salinity higher than 34.50 ‰.

be seen from Table 2, which shows the average bottom temperature and corresponding depths of observations (March—April, 1931—1933) on the fishery grounds at East Lofoten, West Lofoten, Værøy and Røst. The meridian 14°10′ E. is the dividing line between East and West Lofoten.

Table 2.

	1931		1932		1933	
	C°	m	C°	m	C°	m
East-Lofoten	5.52	120	5.45	120	6.69	120
West-Lofoten.....	4.85	104	4.90	104	6.12	106
Værøy and Røst..	4.82	127	—	—	6.60	127

The great difference between the condition of the water masses at Høla during the Lofoten fishery in 1931 and 1932 is clearly shown by Fig. 3. The curves show how temperature and salinity vary as time goes on during March—April in both years. The date of observation is indicated at the top of the figure. Isotherms are drawn for each half degree, and isohalines for each half per mille. The figure shows that the single isotherms as well as the isohalines are nearer to one another during 1933 than in the previous year, a fact that indicates a thinner transition layer between the two types of water in 1933. The vertically shaded area of the figure shows the transition layer between the temperature limits 4.5° and 5.5°. It is immediately evident that this layer was thinner and nearer the surface in 1933 than in the previous year.

Mean depth of	In 1933	In 1932
4.5° limit	63 m.	81 m.
5.5° limit	72 m.	123 m.

It will also be observed that in 1933 the position of this layer varied in depths from time to time, while the thickness of it was comparatively unchanged throughout the season in both years. Whereas the previous year does not show 7° water at all, 1933 shows such from the bottom (160 m.) to 105 m. throughout the season. The shaded area indicates water of more than 6.5°. Once only since 1892 has water of more than 7° been observed at Høla, namely on April 5th, 1930, and then close to the bottom only.

Fig. 4 further shows that the salinity in the lower layers was considerably higher in 1933 than in the previous year. Water of more than 34.5 ‰ (shaded feet) reached from the bottom to about 105 m.; during the previous year there was merely an indication of such salinity. In the upper layers, on the other hand, antithetical conditions are shown.

Fig. 5 shows the distribution at 75 m. of temperature and salinity at Høla. The net of stations consists of 9 stations (plotted on the chart) made from the "Johan Hjort" on March 9th, 1933. It will be noticed that the lowest temperature, 3.5°, has been observed at the outermost station of Høla, from which it gradually increases to 6.5° at the threshold E.S.E. of Kabelvaag. The salinity also increases from 33.10 to

Fig. 5. Temperature and salinity at 75 m. March 9th, 1933.

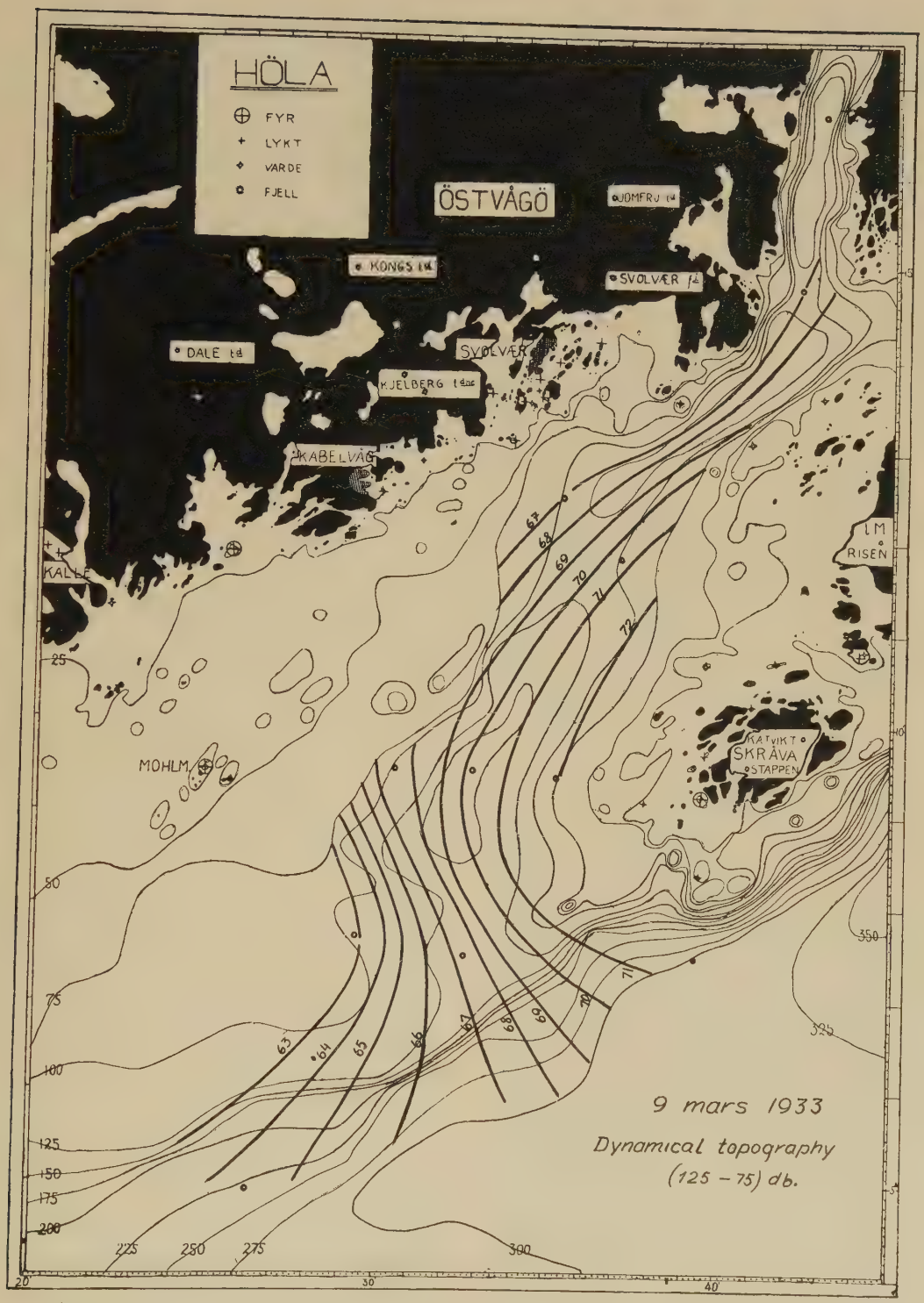

Fig. 6. The dynamic topography of the isobar-surface, 75 db. in proportion to 125 db., the lines for the same dynamic depths being indicated in mm.

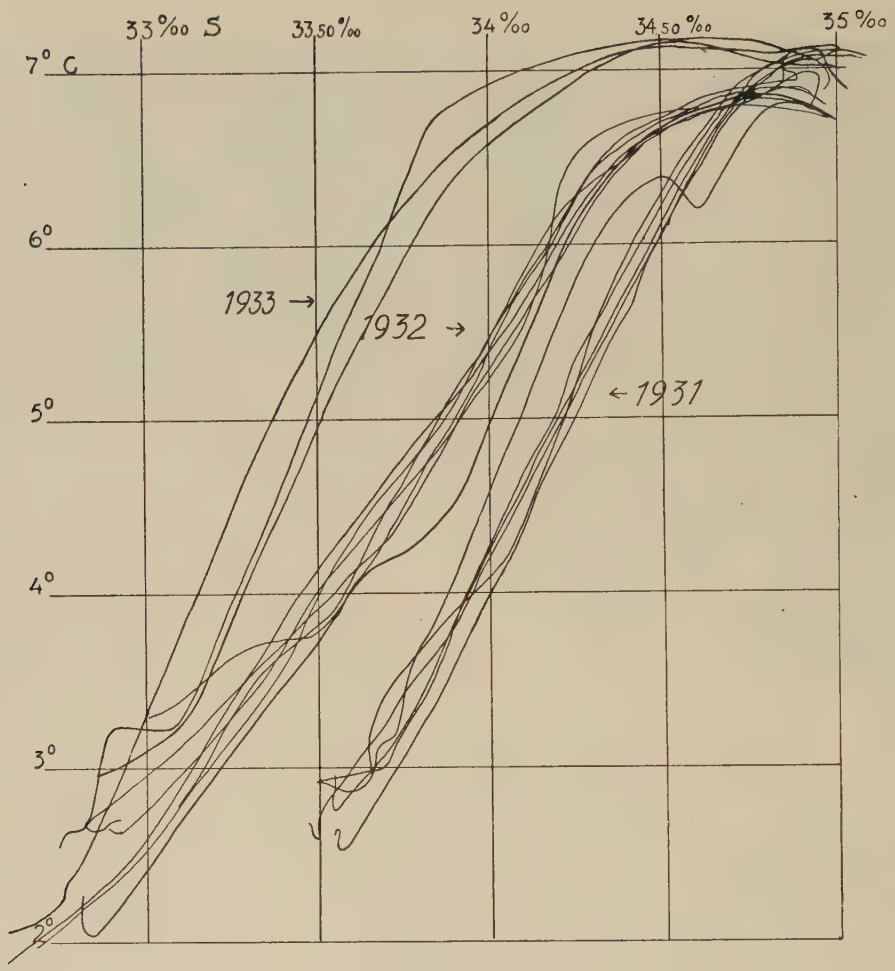

Fig. 7. TS-diagram at Skraava in March—April, 1931, 1932 and 1933.

33.60 ‰ along this stretch. Thus, the water layers at this depth decline considerably from the threshold outwards and in such a manner that the lower layer of warm water lies at a greater depth outside Høla than closer in. From this it would appear that the wind has sucked part of the surface outwards across Høla and thus forced the lower layer to flow inwards and ascend in the inner part. This being the case we should expect higher salinities and temperatures in the surface layer than further out, but this is not the case. Further the wind was eastern and of a force of 3 to 4 (Beaufort scale) for two days prior to and during the observations. The distribution, therefore, must be due to an outflow of water from the inner Vestfjord, this water being forced towards Skraava by the rotary motion of the earth. With an easterly wind the force of the outflowing coastal water increases above normal on this side of the fjord and when passing Skraava some water flows inwards and to the right, from the deeper layer across the shallower Høla. The chart Fig. 6 also indicates such inflow at this depth. It shows the dynamic topography of the isobaric surface: 75 decibars as against the 125 decibar surface, — or the local variation of the thickness of the water layer between the 75 and 125 decibars. The isobars are drawn for each dynamic millimetre. The dynamic depth has been calculated as anomalies, viz. differences between actual values and values corresponding to a temperature of 0° C and a salinity of 35 ‰, at all depths. The chart also indicates an inflow of salter and warmer water from S.S.W. According to the topography, the Høla is a direct continuation of the Austnesfjord, the mouth of which is shown on the chart. In some years an excellent skrei fishery also takes place in the inner fjord.

Surveying all data concerning the water masses of the Vestfjord from NORDGAARD's[1]) investigations in 1896 to the cruises of 1933, it is found that during March—April, 1933, the water masses of the

[1]) HJORT, NORDGAARD and GRAN: Report on Norwegian Marine Investigations 1895—97. Bergen's Museum Bergen 1899.

Vestfjord, between 100 m. and the bottom, have had the highest temperature ever observed at this time of the year.

The fishery was very unstable everywhere at Lofoten during 1933. Occasionally some vessels had good catches, while those fishing close by obtained but poor results. On the same grounds the catches varied considerably from day to day. The fish came near the surface so that nets had to a large extent to be worked way up from the bottom.

Comparing these facts with the oceanographic conditions and remembering the thinness of the transition layer which was near the surface, but varied so considerably in vertical direction that at the depth at which it appeared one day there was no sign of it the next day, a good agreement will be found between the oceanographic conditions and the way in which the fishery developed. When the transition layer is thin the vertical displacements — caused by the inflow of outside water, the wind's accumulation of the surface water, and the sub-marine waves — will become the more noticeable, the scope being so small.

When the results of the fishery vary much it is obvious that the total yield will decrease, and when in 1933 the vessels were forced to fish their nets well off the bottom, it is difficult to get the nets placed satisfactorily, even if the right depth may be found. This also reduces the efficiency of the gear, however, as the current is so much stronger here than nearer the bottom where the gear are usually placed, and particularly at Værøy and Røst this is a great hindrance to profitable catches, as both calculations of the current as well as practical experience have shown that the strength of the current is considerably greater here than at the East Lofoten.

The development of the fishery entitles us to draw the conclusion that the quantity caught is not proportional to the quantity of stock, but that a considerable smaller percentage has been caught than heretofore. When drawing this conclusion, the number of fishermen and the number of trip-days have been taken into consideration.

The development of the fishery in 1931 was similar to that in 1933:— varying! The daily yield was very poor. The transition layer was very thin — just as in 1933 — but was located deeper; the situation was thus more unfavourable in 1933. In 1930, as well as in 1932, the fishery was more even and gave a profitable daily yield. The transition layer was thick for both the years mentioned. In accordance with Rollefsen's and Sund's investigations it was generally the same year-classes which recruited the stock of skrei during all the 4 years. Although the figures below may be incidental, it is nevertheless interesting to compare Sund's calculation of the yield per day's fishing (number of skrei) with the average thickness of the transition layer at Skraava.

	1930	1931	1932	1933
Number of fish per day's fishing	36.5	17.8	27.4	15.5
Thickness of the transition-layer in m.	35	8	20	7

It is necessary, however, to remember the many factors involved, and consequently the above is not a deciding proof of the relation between the yield and the thickness of the transition layer. The question can only be answered definitely after a longer experience.

The character of the water masses in the Vestfjord may change somewhat from year to year, but the variation is smaller within the same season. The T.-S. curves in Fig. 7 will show this. The observations are taken at Skraava at various times during March—April, 1931, 1932, and 1933. It will be seen that the curves for each single year form a separate series, and that of one year is distinctly separated from those of the two other years. In 1932 a higher temperature than in 1931 corresponds to a certain salinity between 33.50 and 34.50 ‰, and in 1933 the corresponding temperatures were still higher. It will be seen that the temperature difference between the two last mentioned years is 2.5° for the interval 33.50—34.00 ‰.

When it comes to ascertaining the causes of the specific oceanographic conditions prevailing in the Vestfjord during the Lofoten fishery in 1933, two dominating factors must first of all be taken into consideration, namely:

1. A heavy inflow of warm and salt Atlantic water (Gulf-stream) into the fjord.
2. Abnormally low salinity of the upper water layers in conjunction with high air temperatures during December and January.

The heavy inflow of Atlantic water has taken place between the autumn cruise in 1932 and the spring cruise in 1933 of the Fishery Directorate. It is, however, difficult to state the time more exactly, as no observations from the Vestfjord are to hand from the period between October 27th and March 7th.

At a depth of about 150—227 m. an inflow of warm water (say 7°) has passed the threshold of the fjord. On account of its higher salinity, its specific gravity was heavier than that of the water which previously was present in the fjord (during the autumn cruise). As the inflowing water passed along the fjord, it has become less heavy by mixing with the other water, and this is the reason why it has not been able to penetrate to the bottom at Skraava, but only to 250 m. (see Fig. 7). At the other side of the fjord, at Øksnes, which is located at a similar distance from the threshold, the new water has reached the bottom, 380 m. This is probably due to the peculiar current condition in the fjord.

From December 30th, 1932, to January 29th, 1933, the average atmospheric pressure in the Iceland area was unusually low, namely 20 milibars below normal, the atmospheric pressure over West Russia at the same time being 17 millibars above normal. The differences of the atmospheric pressure between these two places were thereby 3.5 higher than normal,

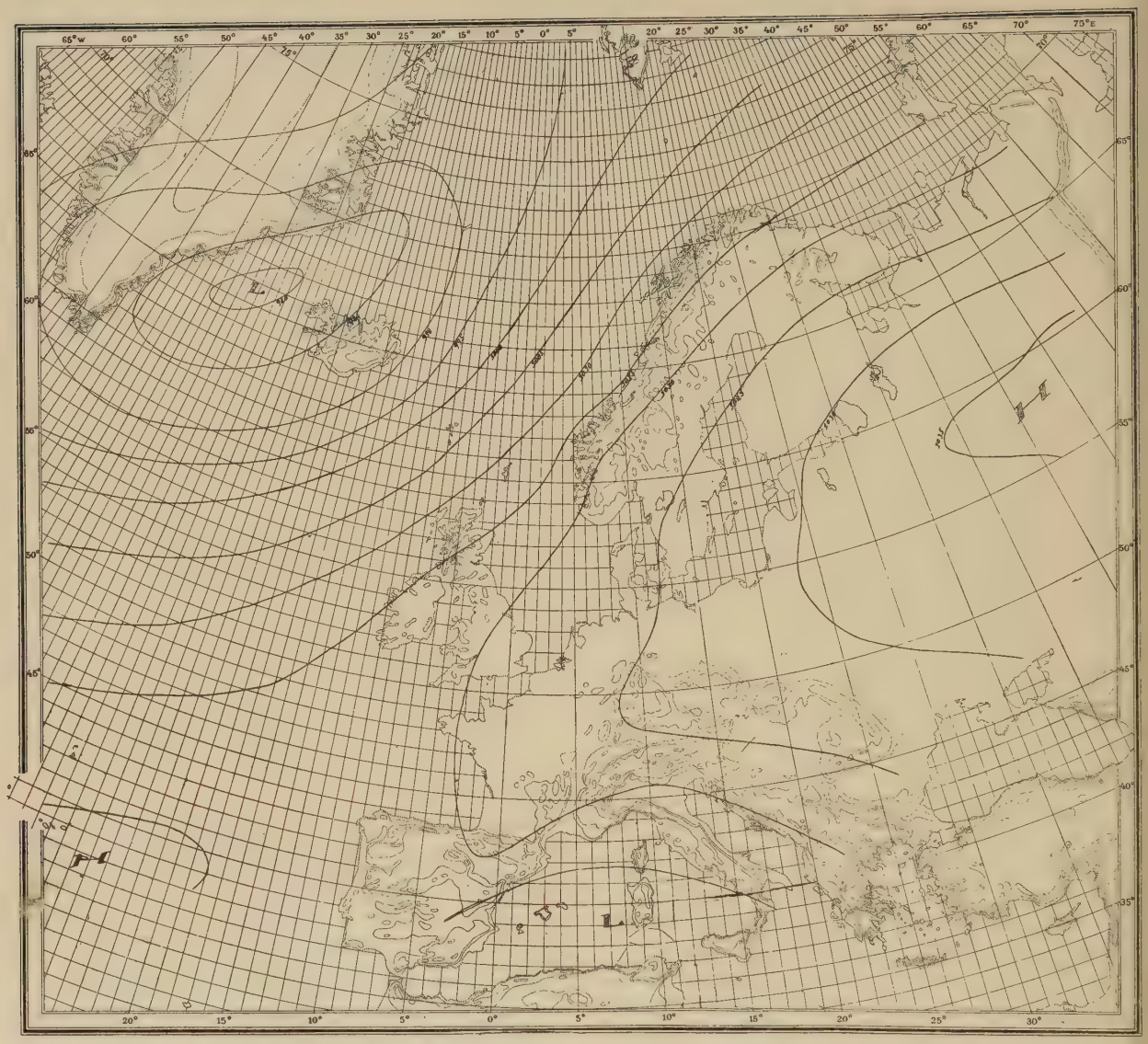

Fig. 8. The mean air pressure, December 31st, 1932—January 29th, 1933.

which caused very heavy and continued southern and south-western winds in the Norwegian Sea. This will be noticed plainly from the charts No. 8 and 9, which Dr. S. Petterson, in charge of the Meteorological Institute at Bergen, has kindly placed at our disposal. Fig. 8 shows the distribution of the average atmospheric pressure during the period mentioned above, and Fig. 9 shows the mean deviation of the atmospheric pressure from the January normal. A similar distribution of the atmospheric pressure will be found also for the latter part of December, while also the tendency in November was the same. Again, the heavy and continued southern and south-western winds caused a strengthening of the Gulf-stream and in connection with the rotation of the earth resulted in greater quantities of warm Atlantic water being forced towards the Norwegian coast.

As the Gulf-stream water generally becomes cooler the higher the latitude it reaches in the Norwegian Sea, the decrease in temperature per km. (subject otherwise to the same conditions) will be less, the more quickly the water masses move northwards, (the turbulence taken into consideration). Furthermore the warm southern air-current caused the surface water to lose less of its warmth than usual through radiation to the atmosphere and environment. The air temperature was very high. At Røst and Svolvær (Lofoten) the average temperature

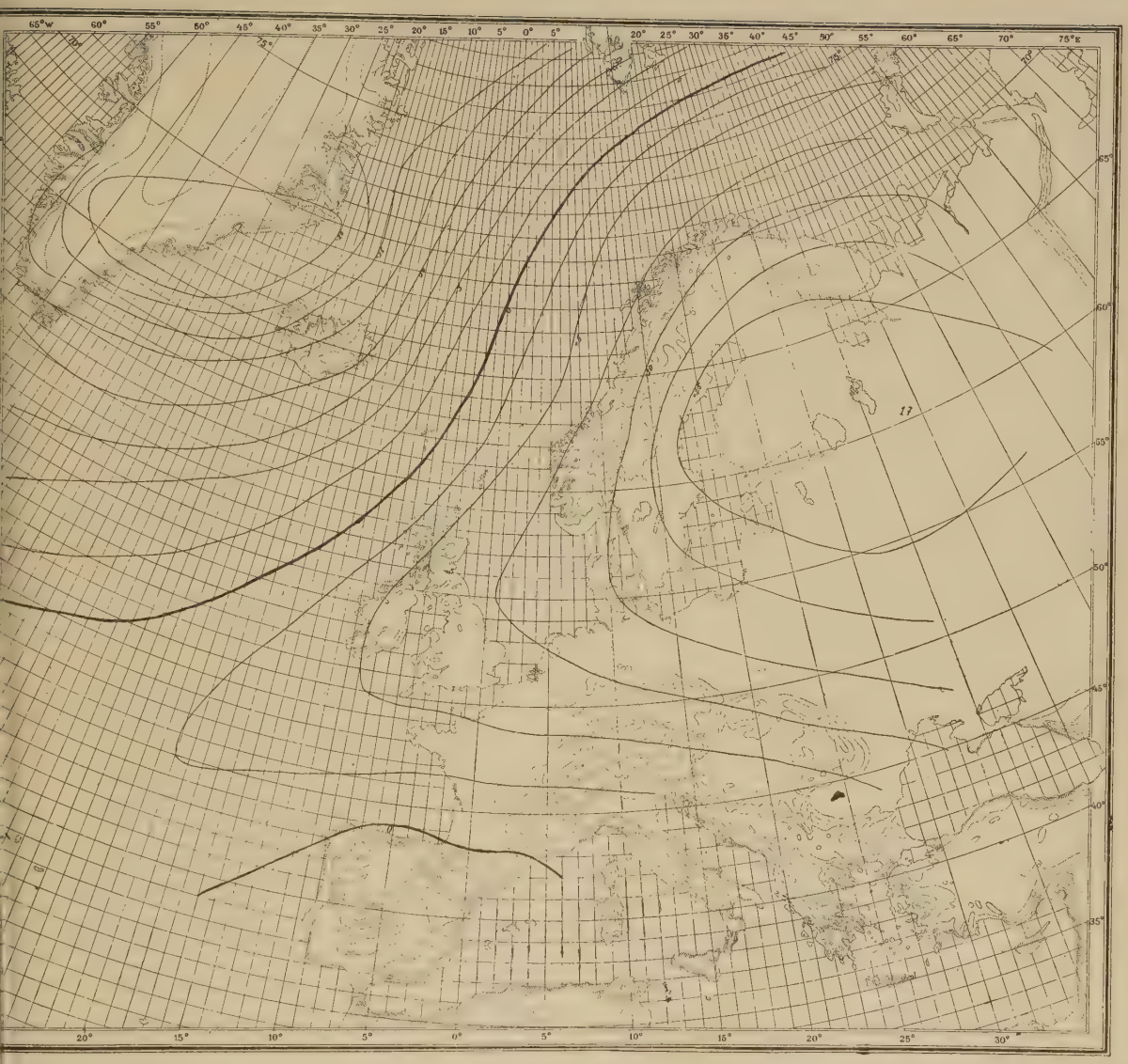

Fig. 9. The mean deviation of the air pressure from the normal, December 31st, 1932—January 29th, 1933.

ng December—January was 2.9° and 4.5° respect-
r. It is the highest air temperature ever observed
e at that time of the year. As regards Svolvær
Røst, observations exist since 1886 and 1876
ctively.

he warm salt water was observed not only in
Vestfjord, but also along other parts of the coast.
he Breitsund at Møre the temperature at a depth
25—250 m. was 0.5 higher than the average
erature of the previous six years, while also the
ity at a depth of 50 m. was considerably higher
the average.

e low salinity of the upper water layers of the Vestfjord resulted in the surface water being so light that, in spite of the winter cooling, it could not sink. Furthermore, as mentioned above, the temperature of the air was very high during December and January. The upper water layers therefore remained like a cushion which resulted in the lower layers cooling very slowly. Moreover the heavy Atlantic water with its high salinity attained a higher level than usual. The combination of these two factors resulted in the transition layer — so important to the fishery — being placed at too high a level and in addition being very thin.

V

THE PELAGIC DISTRIBUTION OF THE HERRING LARVAE IN THE NORWEGIAN WATERS

BY

SVEN RUNNSTRØM, Bergen

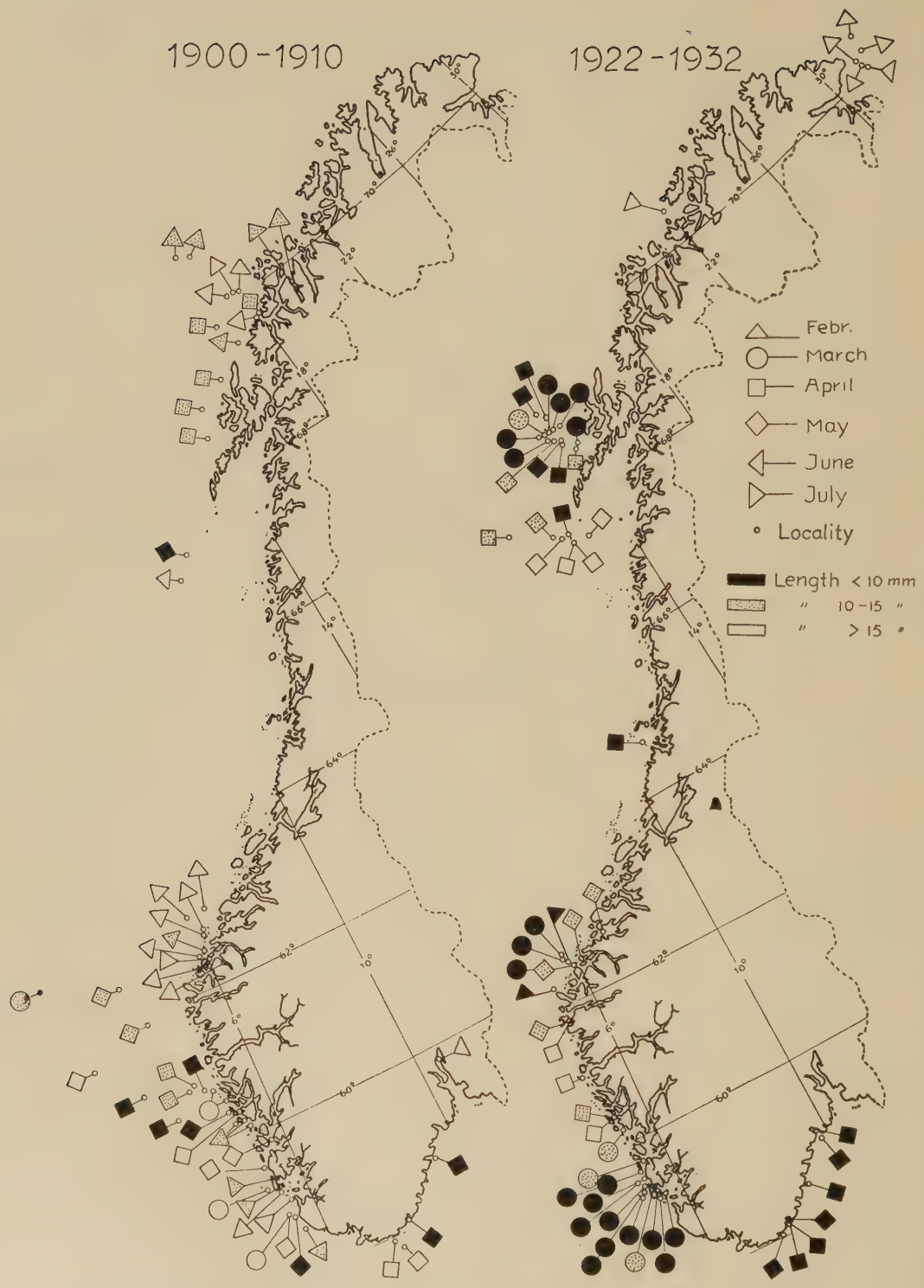

Fig. 1. Places where pelagic herring larvae were taken along the Norwegian coast.

Up to the present no thorough investigation has been made into the pelagic distribution of the herring larvae along the Norwegian coast. This question was taken up with a view to attaining an orientation as to the spawning places of the Norwegian herring by localizing the newly hatched larvae. Our knowledge as to the whereabouts of these spawning places is mainly based upon our knowledge regarding places where ripe herring are caught, but we cannot be sure that this gives us a reliable picture of the conditions. It will also be interesting to follow the drift of the older larvae from the spawning places, as a feature of the migrations of the Norwegian herring.

No special material has been collected for this purpose during the Norwegian investigations, but during the past years a large number of plankton samples have been collected, samples which should be able to elucidate this question. I have now examined this material as far as the herring larvae are concerned and a short summary of the most important results is given below.

The material originates partly from the cruises of the "Michael Sars" during the years 1900—1910, and partly from the cruises of the "Johan Hjort" during the years 1922—1932. It is obvious that these cruises did not cover all parts of the coast, but have been concentrated on certain sections where the large fisheries predominate. Thus, the cruises of the "Johan Hjort", during the seasons which are of interest in this connection, mainly include Lofoten and the Finmark, but some stations have been made on the trips from and to Bergen also.

During later years, this material has been completed by cruises in the spring-herring district south of Bergen, and material has also been collected from the Flødevigen hatchery on the south coast.

Although the stations are not as evenly distributed over the whole coast as would have been desirable, I think nevertheless that the material suffices to give a preliminary orientation as to the conditions. The material includes 6,833 larvae which are measured in millimetres.

The places where the larvae were taken have been marked in the chart (Fig. 1) and the stations have been given various symbols in order to indicate the time of the catches and the size-groups of the larvae. This chart does not show the numerous stations that have produced no yield of herring larvae, nor have I tried to give a survey of the production of herring larvae at the various spawning places, as the material is hardly suitable for this purpose.

The black symbols on the chart, Fig. 1, as well as Table 1 show the distribution along the coast of the smallest length-group of 6—10 mm., chiefly representing larvae with yolk-sack. These newly hatched larvae indicate that spawning must have taken place here or in close proximity. The material of this length-group, which is best represented, originates from the period 1922—1932.

Table 1.

Herring larvae 1900—1932. 6—10 mm.

Locality	Month						
	I	II	III	IV	V	VI	Total
58°—60° N. Skagerak coast / West coast	—	—	—	353	340	—	693
	—	—	1090	—	—	—	1090
60°—62° N.	—	—	—	5	1	—	6
Vikingbank-region	—	—	1	28	—	—	29
62°—64° N.	—	17	2542	—	13	—	2572
64°—66° N.	—	—	—	2	—	—	2
66°—68° N.	—	—	—	12	2	—	14
68°—70° N.	—	—	609	18	—	—	627
Total	—	17	4242	418	356	—	5033

This material shows that spawning takes place along extensive parts of the Norwegian coast, from about 58° to 69° N. lat. But it seems as if certain parts of the coast constitute districts of concentration for the spawning. From 58° to 60° N. lat., both off the Skagerak coast and off the southwestern coast, spawning districts are thus found. The main fishery for ripe spring-herring takes place off the southwestern coast, and the so-called spring-herring district has for years been considered the most important spawning place of the Norwegian herring.

The chart covering the period of 1900—1910 shows, however, that spawning can also take place at a greater distance from the coast on the opposite side

of the Norwegian channel, and particularly so at the Vikingbank; this was also confirmed by Mielck (1929) and Clark (1933).

Another concentration district for newly hatched herring larvae is also located at the Møre coast (62—63° N. lat.). This district includes the so-called large-herring district where the maturing large-herring are caught at the beginning of the season (December—January). The general assumption has been that these herring migrate southwards in order to spawn during February—March on the spring-herring grounds. It will, however, be noticed that a comparatively rich spawning must also take place on the large-herring grounds.

The most interesting feature is, however, the appearance of newly hatched larvae as far north as at about 69° N. lat. Apparently spawning takes place here on the sea banks at Røst as well as off the west coast of Lofoten and at Vesteraalen. These banks should — so far as depth and bottom conditions are concerned — offer favourable conditions for spawning. No fishery for mature herring takes place here, although spent herring are frequently caught from the end of April and during May. Lea (1929) is of the opinion that these herring have spawned on the spring-herring grounds off the southwestern coast and on their way north, after the spawning, are passing Lofoten in May and June. But I think it most likely that in any case part of these herring have spawned on the sea-banks off Lofoten or Vesteraalen.

The material to hand is not sufficient to give any information regarding the amount of spawning at these northern spawning places. The weather conditions during the winter impede a regular collection of material in these open waters and the plankton specimens obtained are comparatively few. In spite of this it has nevertheless been possible to ascertain the presence of newly hatched herring larvae during a series of years, as shown in Table 2. It thus seems that a yearly spawning is certain to take place here. I hope to be able, by means of the bottom-sampler, to make these northern spawning places the object of more thorough quantitative investigations similar to the investigations which I have made during recent years at the southern spawning places.

Table 2.

Herring larvae 6—10 mm. from Lofoten and Vesteraalen.

Year	Month III	IV	V
1909	—	—	2
1922	—	12	—
1928	608	2	—
1929	—	2	—
1930	1	9	—
1932	—	5	—

Table 1 shows also at what season the hatching took place. The specimens collected are not evenly distributed over each of the months, but I believe that the material gives an almost true picture of the conditions and also corresponds very well with the information we possess as to the time of the spawning. We notice that the hatching commences in February, reaching a maximum in March, after which it decreases in April and May. The table further shows that the hatching occurs at almost the same time at the southern as well as at the northern spawning places.

The investigations regarding the distribution of the newly hatched herring larvae show, consequently, that spawning takes place not only at the well-known spawning places near the Norwegian west coast, but also and at the same time at several places along the coast as far north as 69° N. lat. This will help in elucidating the spawning migrations of the Norwegian herring, it being no longer possible to take it for granted that just one single collective immigration towards the southern part of the west coast takes place.

Table 3.

Herring larvae 1900—1932 in size-categories of 5 mm. increment.

Month	Size groups in mm. 6-10	11-15	16-20	21-25	26-30	31-35	Total
I	—	—	—	—	—	—	—
II	17	—	—	—	—	—	17
III	4242	647	2	2	—	—	4893
IV	418	165	158	—	—	—	741
V	356	444	35	9	—	—	844
VI	—	24	136	117	11	—	288
VII	—	—	3	14	25	5	47
VIII	—	—	—	—	—	1	1
IX	—	—	—	—	—	—	—
X	—	—	—	—	—	—	—
XI	—	—	—	—	—	—	—
XII	—	—	—	1	1	—	2
Total	5033	1280	334	143	37	6	6833

In Table 3 and 4 a summary is given of the distribution of all the length-groups, in various months of the year. The larvae have been arranged in length-groups of 5 mm. In Table 3 the material collected from all places of the coast has been treated collectively. A fairly even increase during the spring and summer will be noticed until July when practically all pelagic larvae, so to speak, have disappeared from the catches. As early as the end of June large shoals of the newly metamorphosed individuals may be observed moving along in the coastal waters of the "Skerries" and in the entrance to the fjords. In northern Norway I have observed these young individuals during July and August.

From Table 3 it appears that, in December, two larvae were caught which belonged to the length-groups 21—25 and 26—30 mm. These larvae in no way belong to the rest of the material and they can hardly originate from any herring which spawned in spring, but must have been hatched during the

Table 4.

Herring larvae 1900—1932.

Locality	Month	Size groups in mm. 6—10	11—15	16—20	21—25	26—30	31—35
58°— Skagerak	IV	353	26	—	—	—	—
60° N. coast	V	340	212	—	—	—	—
	VI	—	—	—	—	—	—
	VII	—	—	—	—	—	1
» West	III	1090	646	—	—	—	—
coast	IV	—	—	—	—	—	—
	V	—	—	4	7	—	—
	VI	—	2	1	—	—	—
	VII	—	—	1	—	1	—
60°—62° N.	III	—	—	2	—	—	—
	IV	5	42	147	—	—	—
	V	1	5	10	1	—	—
	VI	—	9	11	1	2	—
Vikingbank	III	1	—	—	—	—	—
region	IV	28	13	1	—	—	—
	V	—	19	11	—	—	—
62°—64° N.	II	17	—	—	—	—	—
	III	2542	—	1	—	—	—
	IV	—	—	—	—	—	—
	V	13	205	10	—	—	—
	VI	—	8	113	96	8	—
	VII	—	—	2	5	1	1
	XII	—	—	—	1	1	—
64°—66° N.	IV	2	28	1	—	—	—
66°—68° N.	IV	12	5	8	—	—	—
	V	2	2	—	1	—	—
	VI	—	—	—	5	1	—
68°—70° N.	III	609	1	—	—	—	—
	IV	18	51	1	—	—	—
	V	—	1	—	—	—	—
	VI	—	3	6	3	—	—
	VII	—	—	—	—	—	—
	VIII	—	—	—	—	—	1
70°—71° N.	VI	—	2	5	12	—	—
	VII	—	—	—	9	23	3

summer or the autumn. The larvae were caught off the Møre coast north of Stat and must originate either from the North Sea herring which spawned in the autumn, or possibly from a local herring shoal.

In order to obtain some idea of the dispersion of the herring larvae from the various spawning places, I have arranged the material in Table 4 according to the various parts of the coasts. It is generally assumed that a great part of the larvae are drifting northwards with the coastal current from the spawning places off the west coast (Johansen, 1927), and that the fry, which grow up in the northern Norway, are recruited from the southern spawning places. The better knowledge now in our possession as to the spawning places of the Norwegian herring leads to the conclusion that part of the fry of northern Norway must in any case originate from the banks off the Lofoten and Vesteraalen, but nevertheless migration of pelagic larvae does take place from the spawning places towards the north. The right hand chart of Fig. 1 shows that, during June and July, pelagic larvae have been caught off eastern Finmark, larvae which must have drifted northwards and eastwards with the current. On the basis of the material to hand it is, however, very difficult to determine the extent of such drift of fry. However, Table 4 shows that pelagic larvae must grow up during spring and early summer at the very spawning and hatching places themselves; this is also the case so far as the spawning places near the southwestern coast are concerned to which no important migration of larvae from the south can take place. Having seen the large shoals of the 0-group during June and July off the west coast, for instance south of Bergen, it is very difficult to imagine that any essential part of the pelagic fry should have drifted northwards. Possibly a large part of the fry drifts into the many fjords along the coast and is thus prevented from further migration towards the north.

A thorough knowledge of the spawning places and the transport of fry is, of course, of great importance for an understanding of the biology and migrations of the Norwegian herring. For one thing the results shown here might help to elucidate the relation between the Norwegian herring and the Murman herring. It has been maintained by several scientists that the Murman herring are identical with the Norwegian spring-herring. It may thus be mentioned that Rabinerson (1925) is of the opinion that the young herring migrate from the spawning places off the southwestern coast of Norway right up to Murmansk. This migration should be favoured by the Atlantic current. Makuschok (1932) has criticised this conception very strongly. He emphasizes that, based on our knowledge regarding the rate of speed of the Atlantic current, a period of two years must be allowed for the transport of a water particle from the west coast of Norway to Murmansk. Rabinerson's material from Murmansk consisted of young herring a little more than one year old. Makuschok is therefore of the opinion that herring so young cannot have been carried from the Norwegian spawning places. He absolutely rejects the migration theory of Rabinerson and is of the opinion that the Murman herring have their spawning places in the very waters where they are caught. We know now that the Norwegian herring do spawn in northern Norway, and even if we — like Makuschok — do not consider coastal currents but take the rate of speed of the Atlantic current into consideration, the fry may be carried from Lofoten to the Murman coast in one year.

The chart of Fig. 1, also shows that pelagic fry may be met with at the eastern part of the Finmark as early as June and July. Consequently there is no reason why the young herring, appearing off the Murman coast, should not originate from the northern spawning places off the Norwegian coast.

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VI

MARKING EXPERIMENTS OF PLAICE *(PLEURONECTES PLATESSA)*

BY

PAUL BJERKAN, Bergen

During the years 1931 and 1932 a lot of plaice were marked and liberated at several localities along the Norwegian coast. Now that most of the recaptures have been made it may be of interest to summarize the results of the experiments.

Marking experiments of plaice have previously been carried out once at the Norwegian coast; viz: at the Lofoten Islands in 1924 and 1925, when 206 and 516 specimens, respectively, were marked and liberated. The results of the experiments are published in "Aarsberetninger vedk. Norges fiskerier 1927, no. 1". The markings of the year 1924 gave a recapture of 9.2 % and those of 1925 a recapture of 29.1 %. Of the latter markings 2 recaptures have been made after the said report, which brings the percentage up to 29.4. The gist of the recaptures was that the plaice during summer roamed about from one fishing ground to the other, but in winter they took to deep water and were caught in scanty numbers in the cod nets during the Lofoten cod fisheries in the Westfjord. No record of recaptures from the deeper water off the Lofoten Islands was received, but this may be attributed to the fact, that no fishery for plaice is going on there, conducted by Norwegians anyhow. One specimen was recorded to have travelled about 128 km. viz: from Kalkunnes on the west side of Moskenes Island to Støt on the mainland. This specimen had been at liberty for about 613 days.

While the previous markings were carried out in the summer, those of the latter years were mostly made during winter, just before the spawning was supposed to set in. By the markings in 1924 only small plaice (below 35 cm.) were marked, later on larger plaice (whole catches) were marked. The latter was mostly also the case as regards the markings during 1931 and 1932, though, now and then, assorted plaice were marked and liberated.

The markings were made in different localities along the coast, viz:

1) 1931, January 10—14th Tananger, near Stavanger.
2) 1932, February 17—18th — —
3) — March 14—16th Berlevaag and Tanafjord, Finnmark.
4) — March 29th Kabelvaag, Lofoten.
5) — October 5—6th Nordvaagsøy, near Stadt.

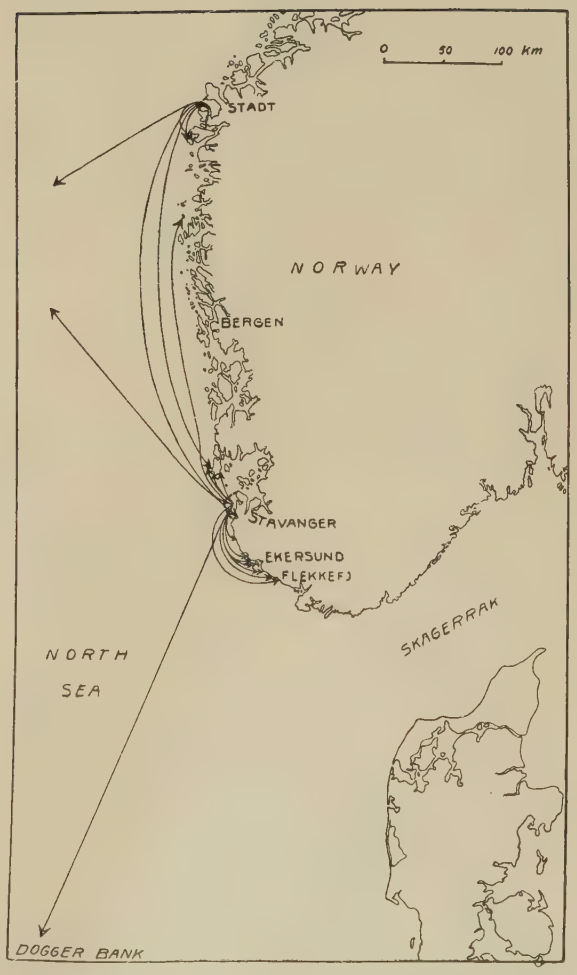

Fig. 1. Recaptures of long-travellers from the marking experiments off Tananger and Nordvaagsøy.

The results of the markings off Tananger (1931 and 1932) and off Nordvaagsøy (1932) are shown in Fig. 1. Only the long-travellers have been marked off with separate lines i. e. plaice, which have travelled more

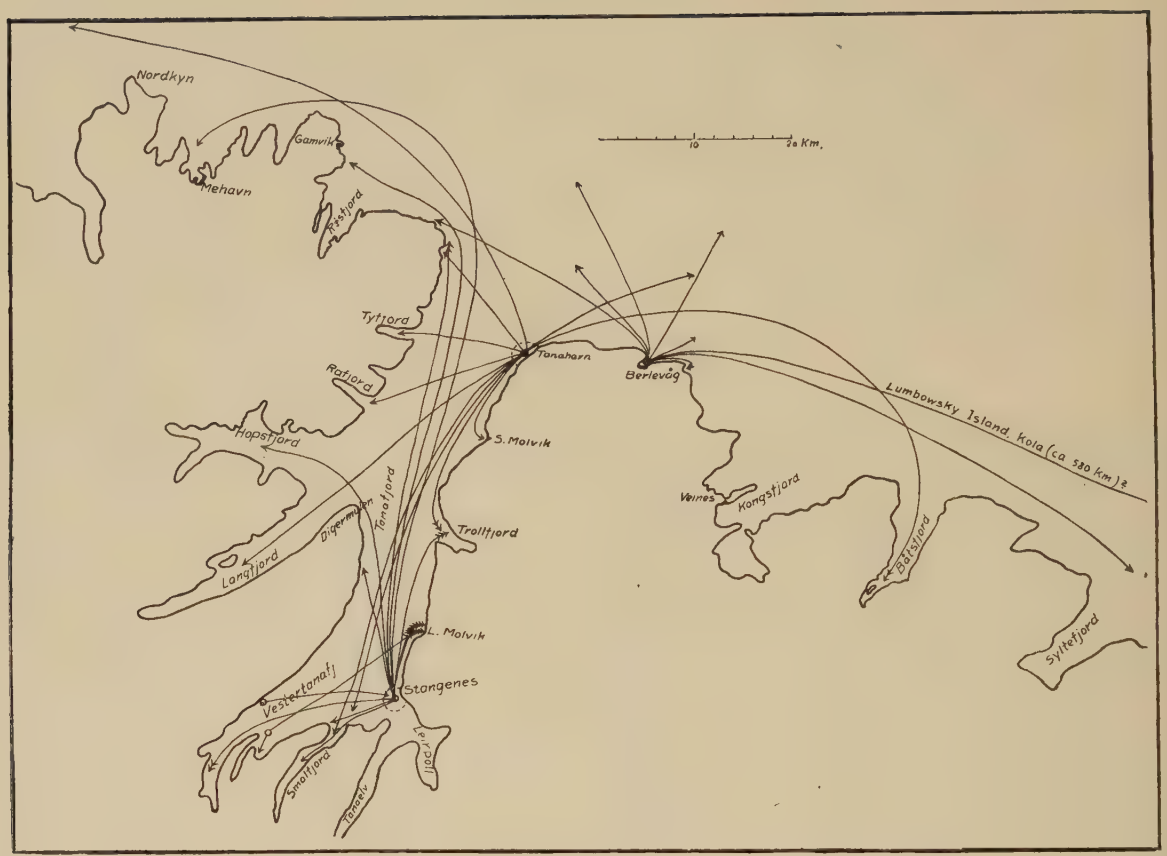

Fig. 2. Recaptures of long-travellers from the marking experiments off Berlevaag and in the Tanafjord.

than 15 km. The map has been chosen in a very small scale in order to show the overlapping of the wanderings of the plaice from the two localities, Tananger and Nordvaagsøy.

By the markings off Tananger 1931, 91 plaice were marked and liberated, 19 of which were recaptured, i. e: 20.9 %. Of those recaptured, 10 have travelled more than 45 km., the rest from 2—10 km. Thus, more than half the number are long-travellers. As may be seen, they have travelled in different directions, north and south along the coast and out into the North Sea. The latter are the most interesting ones, as they have traversed the Norwegian Channel and have been taken by British and German trawlers in the North Sea. The plaice recaptured at North Shoals, Dogger Bank, had in 99 days travelled about 520 km., which gives more than 5 km. a day.

By the markings off Tananger 1932, 233 plaice were marked and liberated. Recaptures up to the end of 1933: 84 specimens, i. e. 36.5 %. 7 only of these had travelled more than 15 km., the rest from 2—14 km. Of those recaptured, thus, only 8 to 9 per cent were long-travellers, the rest was roaming about from locality to locality on the fishing grounds near Tananger. It is, however, to be noted that only some few specimens were taken at the very locality, where they had been liberated.

The markings off Nordvaagsøy were carried out in autumn and therefore very few long-travellers have been recorded. 157 specimens were marked and liberated. 60 of these were recaptured up to the end of 1933, i. e. 38.2 %. Only 5 had travelled from 19—370 km., the rest from 1—10 km. Of those recaptured, thus, only 8 to 9 % were long-travellers. The trend of the wanderings of these seems to be southward, no recaptures having been recorded to the north of Stadt. The majority of the plaice liberated seems to have roamed about from locality to locality in the waters adjoining Sildegapet to the south of Stadt.

One specimen has traversed the Norwegian Channel and was taken by a German trawler on the slopes towards the North Sea banks. Two specimens have travelled very far to the south. One of these was taken in the vicinity of the marking place off Tananger and has travelled about 370 km. in 287 days, i. e., 1.3 km. per day, the other about 330 km. in 226 days, i. e., 1.5 km. per day. The migrations of

the plaice from the two marking localities thus overlap each other and an exchange may be effected, especially during the spawning times.

In Finnmark markings were made at 5 different localities, 2 at and in the mouth of Tanafjord and 3 in the inner part of the said fiord.

In the outer part of this fiord 91 specimens were marked. 13 of those liberated near the wharf in Berlevaag harbour were, however, taken up the next day as dead. This was caused by bad handling owing to an accident (fire in the engine room of the motorboat during the markings). In the following I therefore take into account the remaining number of 78 specimens only. Of this, 32 have been recaptured up to the end of 1933, i. e. 35.2 %. 9 specimens were recorded as captured by British and German trawlers, mostly within a period of 2 months after the liberation. About half the number of the plaice recaptured have travelled more than 15 km. One has been recorded as taken off Lumbowsky Island, Kola after 35 days. This statement, however, I find somewhat dubious. The distance is about 580 km., which gives a travelling rate of about 16.5 km. a day, and this seems to be quite inconceivable. The British trawler in question must have fished off Lumbowsky Island and, on the way home, taken replenishing catches off the Finnmark coast, and then the whole catch has been recorded as taken in the Barents Sea.

In the inner part of the Tanafjord 176 specimens were marked and liberated at 3 localities. The majority of the plaice, 156 specimens, were liberated at Tana Bank near Stangenes, just outside the mouth of the Tana River. On this bank there is an accumulation of young plaice, at times found in larger quantities. The farther in on the bank, the younger and smaller the plaice are.

Of the plaice marked and liberated in this part of the fiord 52 specimens have been recaptured up to the end of 1933, i. e.: 29.5 %. Of the plaice recaptured 13, that is 25 %, have travelled more than 14 km. The trend of the wanderings is out of the fiord, but an exchange of plaice between the arms of the fiord in the inner part is found in some cases. 4 specimens have travelled from Tana Bank to the open sea, to Russeviken (2), Gamvik (1), and Mehavn (1), viz: about 48, 60 and 84 km., respectively.

In Fig. 2 the results of the marking experiments for the plaice which have travelled some distance are shown. Seen as a whole there seems to be a little or no special trend in the wanderings. The plaice travel from locality to locality, mostly, though, out of the fiord or out to sea. Some, however, marked in the outer part have travelled a longer or shorter distance into the fiord and it is conceivable that many of the plaice which take to the open sea towards the spawning time, may return to the coast later on and that the trend towards the open sea is a result of a tendency caused by the spawning only.

The Tana Bank, however, seems to be a nursing ground for the plaice, and when they grow up they scatter all over the fiord and the coast towards the open sea. This seems to be confirmed by the shorter as well as by the longer wanderings as shown by the illustration.

The results of the markings seem to confirm the idea that the plaice population on the outer banks and that of the coast and the fiords are one and the same, and that an exchange takes place. The plaice grow up at suitable localities in the fiords and bights along the coast and later on recruits the population farther out at sea.

The recent marking experiments at Lofoten Islands were more incidental. An experiment at the time of propagation of the plaice was conducted in an aquarium at Kabelvaag. The females were afterwards killed and examined as to ripeness and conditions of gonads, and the males, 41 specimens, marked and liberated near the wharf of Kabelvaag.

Of these 20 specimens were recaptured, i. e. 48.8 %. Many of the plaice liberated were recaptured in nets not far from the place of liberation. Some few, however, were recorded as caught after longer wanderings, up to about 50 km., one in Napstrømmen, a habitual locality for the population of plaice in Lofoten waters. 4 had travelled as far as Henningsvær, 13—15 km. As might be seen from Fig. 3, the trend of the migrations of the recaptured plaice seems to be westward, out to the banks and fishing grounds mostly frequented by the plaice fishermen in Lofoten waters. By the other marking experiments treated here the plaice were marked and liberated at or near the locality where they were caught. In the latter case, however, they were first transported to Kabelvaag and then, after some time, liberated. This circumstance may be taken into consideration in a discussion as to the westward trend of the migrations.

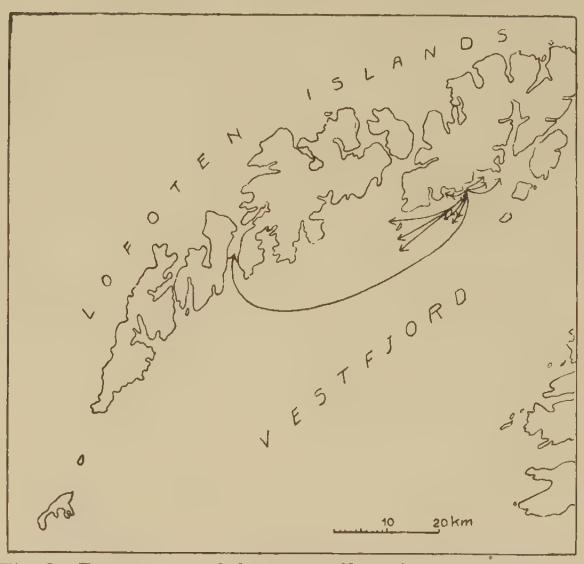

Fig. 3. Recaptures of long-travellers from the marking experiments off Kabelvaag.

As a whole the marking experiments treated here have shown, regarding the migrations of the plaice, that there is an exchange between the different parts of the coast and between the coasts and fiords and the banks farther out to sea. Conspicuous in this connection are the specimens which have traversed the Norwegian Channel and have been taken in the North Sea proper. Observations tending in the same direction have been made before, viz: that plaice marked when young in the fiords of western Sweden, later on, when mature have been caught at the Norwegian coast near Egersund and off Karmøy.

By the investigations and the marking experiments at Lofoten in 1924 and 1925 I found that there was a distinct difference in the habits of the plaice found at the different localities. At the fishing ground off the Lofoten Islands the plaice during summer time was mostly feeding on sandeel (*Ammodytes*) and roaming about from fishing ground to fishing ground. In other localities as Napstrømmen they were mainly feeding on mollusks and were more stationary. At the grounds first mentioned the fishermen might get large catches one day and the next day none at all, at the others they could fish for a period, though with diminishing catches, on the more stationary plaice population.

By the recent marking experiments this supposition has been confirmed. There are more stationary populations which may for some time give good catches, but the best catches, at least those by the Danish seine, are made when the plaice gather to feed on the sandeel-shoals swarming up through sandy channels (siilveiter) towards more shallow water. Then is the time for the Danish seine which can only be used where the bottom is more even. An exchange between the more local and the more migratory populations may take place, but the plaice fishermen maintain that there is a distinct difference in colouring etc. between the local and the migratory plaice, though transition stages may be found.

Most of the bottom along the coast of Norway is too rough for the use of the Danish seine, only here and there patches of even bottom are large enough to give room for this comparatively light fishing gear. Smaller patches of sand are found in many places along the rougher ground and the plaice is usually found roaming about everywhere there. This is just one of the good traits in the fishing conditions of the Norwegian coast, as regards the plaice. It is so to say a natural protection of the coastal plaice population of no slight importance.

VII

COD-MEASUREMENTS DURING 21 YEARS ON THE WESTERN AND NORTHERN COASTS OF NORWAY. METHODS AND RESULTS

BY

OSCAR SUND

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I. Some Remarks on the Measurements of Fish.

1. Choice of Unit. Handbooks on biological statistics require generally that a series of measurements of a *homogeneous* material must be carried out in such units as will give 15 to 20 classes. As the entire range of variations of a homogeneous distribution is about 6 times as large as the standard deviation the result is a class-margin that ought to be one third of this. If for the time being we reduce the requirements of homogeneity for the series of individuals belonging to the same year-class we reach a class-margin which should be about 1 % or 2 % of the average length of the series, e. g. in respect of herring and cod (see tables 1 and 2).

Table 1.

Length variation in the 1904-brood of herring. Per-mille distribution on cm.-classes.

a) caught Aug. 1909 as fat-herring. Sample of 282 ind.
b) caught Sept. 1909 as maturing fish. Sample of 197 ind.
c) caught Oct. 1909 as maturing fish. Sample of 246 ind.
d) caught Feb. 1914 as spawning fish. Sample of 351 ind.

Cm.-classes	Samples a	b	c	d
22	4	—	—	—
23	—	—	—	—
24	82	—	—	—
25	326	—	—	—
26	309	5	—	—
27	184	10	53	—
28	60	183	212	—
29	25	503	405	—
30	11	264	303	6
31	—	36	29	120
32	—	—	—	453
33	—	—	—	339
34	—	—	—	68
35	—	—	—	14
Average length, cm.	25.9	29.1	29.0	32.4
Standard dev. cm.	1.21	0.81	0.92	0.86
do. in % of average	4.82	2.80	3.15	2.64

Table 2. Length variation within single year-classes of cod, the age determined by G. Rollefsen by means of otoliths. (Measured to nearest cm.).

Length (cm.)	10 years	11 years	12 years
66— 70	1	1	—
71— 75	11	4	2
76— 80	20	16	7
81— 85	16	30	12
86— 90	18	37	22
91— 95	12	22	19
96—100	5	6	21
101—105	1	1	4
106—110	—	—	4
Total	84	117	91
Average length	83.9	86.2	91.1
Standard dev.	7.65	6.32	7.90
do. in % of average	9.1	7.3	8.8

This again results in measurements of full-grown herring being divided into measurement classes of no more than $^1/_3$ cm., and those of full-grown cod no more than 2 cm. This, however, does not agree with common practice which nearly always purports to give measurements of herring in whole centimetres and those of cod in 5 centimetre-groups. H. J. Buchanan-Wollaston also agrees in principle with the necessity of the class interval being proportional to the mean ("A New Method of Treating Frequency Curves . . .", Journal du Conseil, Vol. IV, No. 2, p. 210).

This author goes even so far[1]) as to wish to divide an ungraded series of measurements into classes the intervals of which increase with the argument of classification. Without going into the practical and theoretical side of this principle it may at once be said that he carries this through on a basis which seems both casual and hardly suitable, inasmuch as he fixes 1 cm. as a suitable interval for the class the mean value of which is 15 cm.

[1]) "Some remarks on the graduation of measurement data, Journal du Conseil, Vol. VI, No. 1, 1931".

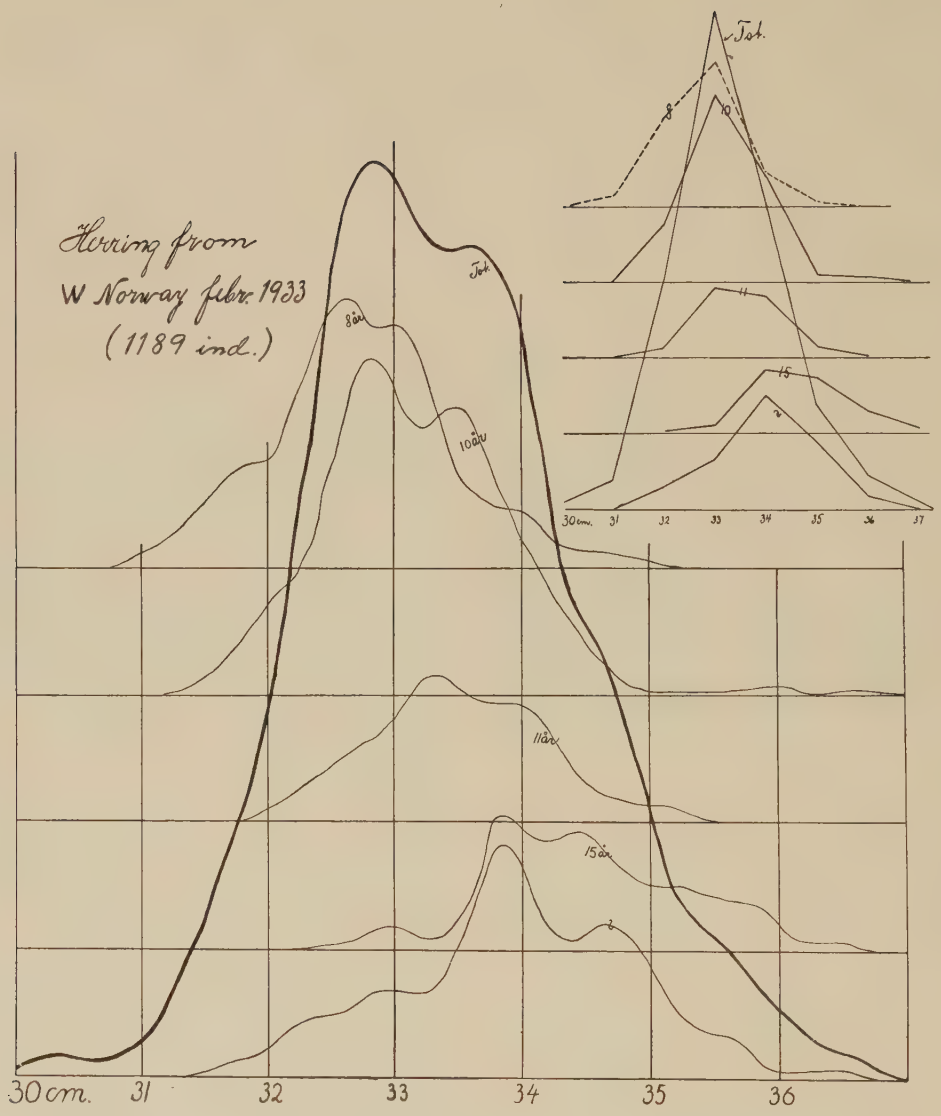


Fig. 1. Sample of herrings measured in units of 2 mm. and divided into age-groups. Upper right-hand diagram: the same data contracted into cm.-classes.

In both works cited BUCHANAN-WOLLASTON maintains that the year-classes into which a catch must be divided do not in any way (generally) constitute a homogeneous distribution. In most cases it may be noted that the age-group consists of sub-groups. In this connection there is no reason to go into the question as to the causes of sub-divisions of this kind; it is certain that they exist with cod as well as with herring and plaice, and most likely with all fish in the open sea. To succeed by means of a series of measurements in showing a fairly true picture of such sub-groups, it seems natural to give the results of such measurements by classes at least as narrow, or even narrower, than the standard which can be deduced from the breadth of distribution of a year-class, 1 % or 2 % of the mean length of the series.

As an example of attainable results, for instance by measuring herring in intervals which in any case are less than 1 % of the mean length of a year-class, Fig. 1 is given, showing 2 ways of presenting the same material resulting from 1189 spawning herring from West Norway (February, 1933), measured in classes of 2 mm. and age-determined by Mr. TH. RASMUSSEN, the Fishery Directorate, Bergen. The main figure shows the size distribution after a slight smoothing (according to the formula $(a + 2b + c):4$ where a, b and c indicate the successive frequencies). The most frequent year-classes only are included in

Table 3. Age and size distribution of spring-herring.
Measured to nearest fifth of one cm. and age-determined by TH. RASMUSSEN.
Six samples from West Norway, seine-caught, February 1933.

Year-class / Length (cm.)	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	?	Total
< 30.0	1	5	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	8
.2	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	3
.4	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
.6	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
.8	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
31.0	—	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	3
.2	—	—	—	3	3	1	—	—	—	—	—	—	—	—	—	—	—	7
.4	—	1	—	3	4	2	1	—	—	—	—	—	—	—	—	—	—	11
.6	—	—	1	6	11	2	2	—	—	—	—	—	—	—	—	—	1	23
.8	—	1	—	4	7	1	6	—	—	—	—	—	—	—	—	—	2	21
32.0	—	1	2	1	16	6	10	1	—	—	—	—	—	—	—	—	2	39
.2	—	—	—	7	15	5	10	4	1	—	—	—	—	—	—	—	6	48
.4	—	—	1	7	22	10	17	3	1	—	—	1	—	—	—	—	7	69
.6	—	—	1	8	35	5	28	9	1	1	—	—	—	—	—	—	4	92
.8	—	—	—	4	16	7	38	6	2	2	—	2	—	—	—	—	11	88
33.0	—	—	—	3	31	8	29	11	1	—	—	3	—	—	—	—	7	93
.2	—	—	—	1	20	5	24	15	5	1	1	1	—	—	—	—	9	82
.4	—	—	—	5	13	5	29	15	3	—	—	—	1	—	—	—	8	79
.6	—	—	—	3	7	3	31	11	8	1	1	6	—	—	—	—	16	87
.8	—	—	—	2	5	3	18	12	2	—	—	8	—	—	—	—	26	76
34.0	—	—	—	—	8	2	18	12	2	1	1	17	—	—	—	—	22	83
.2	—	—	—	—	2	—	9	10	4	1	1	10	1	—	—	—	12	50
.4	—	—	—	—	2	2	8	4	2	5	—	10	—	—	—	—	13	46
.6	—	—	—	—	2	—	3	3	2	4	—	13	—	—	—	1	16	44
.8	—	—	—	—	1	—	1	2	2	2	—	11	1	—	—	—	15	35
35.0	—	—	—	—	1	—	—	2	1	3	1	7	—	—	—	—	12	27
.2	—	—	—	—	—	—	1	2	—	—	1	6	—	—	—	—	5	15
.4	—	—	—	—	—	—	—	—	—	1	—	7	1	—	—	—	4	14
.6	—	—	—	—	—	1	1	—	—	1	—	6	—	—	—	—	6	15
.8	—	—	—	—	—	—	1	—	—	—	1	4	—	—	—	—	1	7
36.0	—	—	—	—	—	1	—	—	—	1	—	6	—	—	—	—	1	9
> 36.0	—	—	—	—	—	—	1	—	2	—	—	6	—	—	—	—	2	8
Total	2	13	7	60	223	69	286	122	39	24	7	124	4	0	0	1	208	1189

The same condensed into whole cm.-classes:

Year-class / Cm.-class	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	?	Total
27	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
28	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
29	1	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	4
30	1	3	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	6
31	—	3	2	6	9	3	1	—	—	—	—	—	—	—	—	—	—	24
32	—	2	4	25	71	24	45	8	2	—	—	1	—	—	—	—	18	182
33	—	—	1	21	115	30	148	56	12	4	1	6	1	—	—	—	39	395
34	—	—	—	5	24	10	84	49	18	8	3	51	1	—	—	—	89	243
35	—	—	—	—	4	—	5	9	5	10	2	44	2	—	—	1	52	82
36	—	—	—	—	—	2	3	—	1	2	1	18	—	—	—	—	10	27
37	—	—	—	—	—	—	—	—	1	—	—	4	—	—	—	—	—	5
Total	2	13	7	60	223	69	286	122	39	24	7	124	4	0	0	1	208	1189

the diagram; in the corresponding table (Table 3) all data are given. It is obvious from the above that each year-class consists of several groups as well as that the total curve also indicates that the matter is not quite so simple as it might appear from a measurement in the customary unit, 1 cm. The more exact measurement also seems to give a useful indication in respect of the age of the individuals which

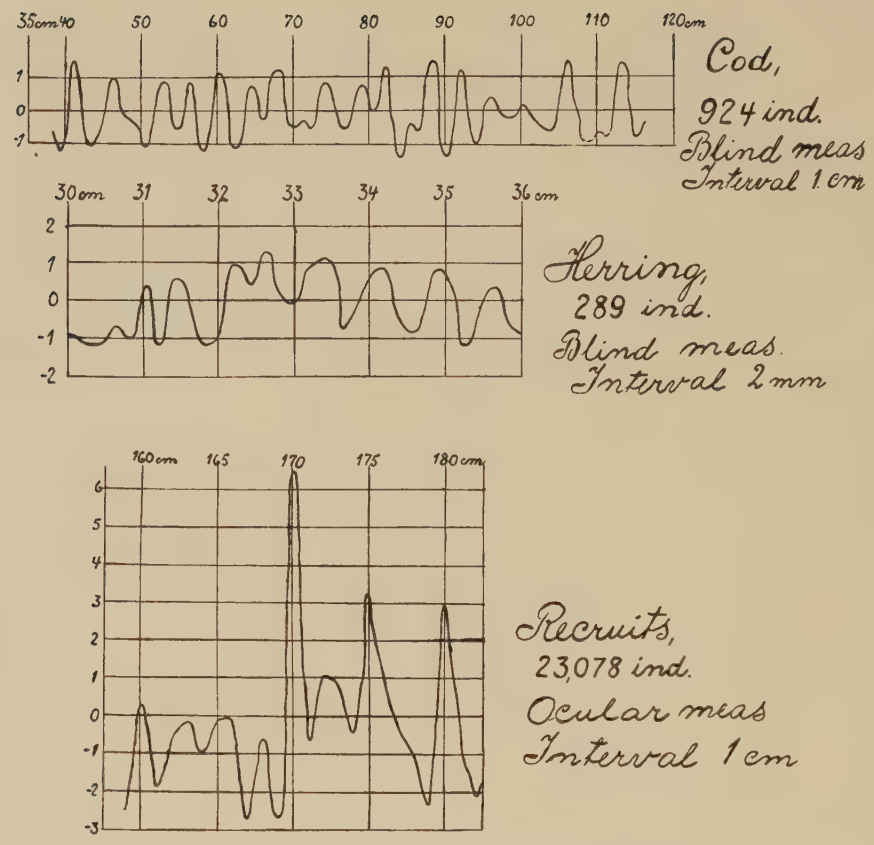


Fig. 2. 3 measurement series showing different types and extent of "irregularities", i. e. differences from a series formed by excessive smoothing of the identical data. The ordinates of these curves, y' are formed in this way:

$$y_x' = \frac{y_x - (y_{x-2} + y_{x-1} + y_x + y_{x+1} + y_{x+2})/5}{(y_{x-2} + y_{x-1} + y_x + y_{x+1} + y_{x+2})/5}$$

where y represents the original frequencies.

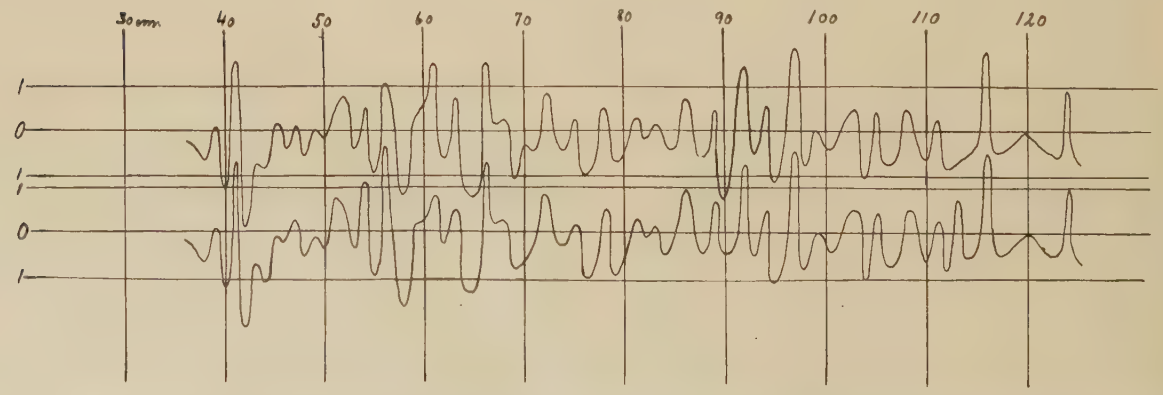


Fig. 3. Two curves constructed in the same way as Fig. 2, form the same set of ungrouped data, grouped by two different persons, to show absence of appreciable personal influence on the grouping.

are included in the bottom curve, inasmuch as the age could be read from the scales. Based on a measurement in centimetres it would be assumed that the majority would be put into the 15th year-class, but the position of the second highest modus, deduced from measurements in 2 millimetre-groups, shows that a large number of 16 year old individuals must exist amongst the individuals of unknown age.

Likewise by subdivision of measurements of herring and other fish of similar size, all details of interest disappear when groups of 1 cm. are chosen, while quite uninteresting curves are also obtained for cod measurements in 5 cm.-groups, when compared with results obtained by a finer group-classification. The fact that the meaning of all details in such curves is not always understood rather emphasizes that observed facts should not be hidden or smoothed by too much generalization. No adequate explanation can thus be given to the very characteristic unevenness of the curves in Fig. 3 which would disappear if the material was divided into 5 cm.-groups instead of 1 cm.-groups. It cannot be denied, though, that it will be possible, in future, to draw certain conclusions from such irregularities as to the growth of cod for instance. Experiments with a classification of cod into half cm.-groups, however, have not produced diagrams essentially different from the 1 cm.-groups. We have, therefore, kept 1 cm. as a suitable interval for "full-grown" cod of the sizes generally occurring in Norwegian catches (35—140 cm.) or about 0.6 to 3 % of the length.

Unfortunately, we have made no experiments with the Buchanan-Wollaston division into groups with "proportional" intervals, but when doing so, it will not be with a division into groups of 6 % of the length in each class, as suggested by him, but of 1 %-groups, in order not to lose any details existing in the material. The method seems well founded and well worth trying in measurements of various other kinds of fish.

2. Method of Measurement. Until a few years ago the universal method of measuring fish was to determine, by means of a divided tape or board, the length of the fish to the nearest unit desired for the representation of the data, only exceptionally to a unit of smaller compass. Apart from the fact that this procedure incurs extra work inasmuch as measurements have to be recorded and afterwards to be tabulated, there is the danger of two kinds of errors: on the one hand an error in reading as well as in recording, and on the other the error — arising from the fact that almost everybody will have a partiality for certain figures, particularly round ones, or, if aware of this fact, he will have a corresponding "horror" of such figures. The result from such measurements may thus be ruined to the extent of their being practically useless. An example of this is to be given later.

Fortunately, there is an alternative method of measuring which not only eliminates this disadvantage, but also gives a number of other advantages. It is the method which may be termed the "blind" method, first mentioned by Buchanan-Wollaston in Journal du Conseil (Vol. III, No. 3). He recommended measuring fish by placing them on a board on which is fastened a celluloid slip, bound with some protecting material, and by piercing this slip with an awl at the tip of the tail of each fish. In the following issue of the Journal du Conseil, d'Arcy Thompson draws the attention to the fact that he had previously recommended a similar method, but with millimetre paper in lieu of celluloid. In both cases a higher degree of precision is attained as well as the possibility of counting the marks in any groups desired, in other words "un-grouped" measurements are made. Experience proves also that the method is considerably quicker, a fact of economic importance, and in many cases of decisive importance in order to obtain any measurements at all, as with commercial catches which frequently have to be handled and dealt with in the shortest possible time.

In order to test the accuracy of such "blind" methods, we have in certain cases made repeated measurements of the same fish in groups of ten specimens. The results are set out in table 4 which shows that the standard deviation of a single awl-measurement was 1 to 2.5 mm. In some cases the same ten fish were measured "ocularly". Four, at least, of these measurements (in the table indicated by an asterisk) proved erroneous by one unit.

A very good example of the superiority of the awl-measurements versus ocular-measurements is obtained when calculating the deviation of each frequency from those obtained by a considerable smoothing of the respective series of measurements. This procedure is an extended use of the formula of G. Udny Yule (Introduction to the Theory of Statistics, London 1912, Ch. Griffin). According to Yule, the standard deviation of a frequency of a series of measurements that follows the laws of error, equals $\sqrt{f\frac{N-f}{N}}$. Measurements of fish are hardly ever subject to any distribution in strict accordance with the laws of error, but nevertheless the method may be used, if the actual distribution is compared with a considerable smoothing of the series in question, instead of applying the ideal distribution in accordance with the laws of error, for instance by making consecutive means of five consecutive frequencies. If the difference between the actual frequencies and the corresponding frequencies in the smoothed curve is given in units of the standard deviation of the frequencies, calculated in accordance with Yule's formula, in which f indicates the frequencies in the smoothed curve, and N the sum of the frequencies, it will be seen from Fig. 2 that awl-measurements will result in regularly consecutive deviations (positive and negative), not exceeding once the standard deviation. The lower diagram of Fig. 2 shows, however, the deviation of the frequencies within a large series of ocular-measurements, recruits in Norway in 1928. The curve is

Table 4. Repeated measurements of ten fish by three separate persons.

I) Andenes, January 19th, 1933.

Cod number	1	2	3	4	5	6	7	8	9	10
Ocular measurement (cm.)	69	74	76	81*	84*	86	90*	93*	97	99
Single, very accurate blind measurement	687.5	735.5	756.5	803.0	831.5	857.0	893.5	919.0	964.0	983.0
Average of 10 ordinary blind measurem.	687.4	735.8	761.0	804.2	831.7	859.2	894.2	921.6	966.3	987.7
Standard deviation of same (mm.)	2.16	1.72	5.00	3.34	2.54	1.90	3.20	1.75	1.10	2.14

Standard deviation of all 100 measurements: 2.46 mm.

II) Værøy, March, 1933.

Cod number	1	2	3	4	5	6	7	8	9	10
Average of 11 common blind measurem.	646.4	709.4	773.2	796.5	834.5	866.3	919.3	1018.1	1047.5	1071.3
Standard deviation (mm.)	0.9	3.3	1.1	3.0	2.2	2.0	1.4	2.2	1.1	2.8

Standard deviation of all 110 measurements: 2.08 mm.

III) Kabelvåg, March 31st, 1933.

Cod number	1	2	3	4	5	6	7	8	9	10
Average of ten (blind) very careful measurements	714.0	750.6	828.9	857.2	914.0	953.7	985.2	1001.4	1040.4	1115.4
Standard deviation	0.9	1.2	0.9	0.7	0.9	1.0	1.1	1.1	1.1	1.3
Average of ten ordinary (blind) meas.	714.0	749.6	829.5	857.2	915.0	952.6	984.2	999.9	1039.8	1116.0
Standard deviation	0.7	1.5	1.6	0.7	0.9	1.2	1.2	1.0	0.8	0.8

Standard deviation of all 100 "very careful" measurements: 0.985 mm., of the 100 "ordinary" measurements: 1.03 mm. Sum of differences between the two series of measurements on the same ten fish: 0.3 mm.

here very irregular, with exceedingly large positive deviations from the round arguments. The vertical scale in all the three diagrams indicates the deviations with the standard deviation as unit.

If for any reason it has not been possible to use the ocular measurements, for instance when individual scale or otolith samples are wanted, the main disadvantages of the ocular measurements may be avoided by measuring by a unit which is the smallest possible, and then later arranging the measurements in accordance with the requirements.

When grouping "un-grouped" data some uncertainty may arise as to the variants which are within the limits of the groups required. Fig. 3 shows that the risk of having the material misrepresented is very small, the awl-measurement-series of 2142 cod (grouped by two persons) indicating this, after having been treated in the manner mentioned above.

II. The Numerical Treatment and the Graphical Presentation of the Norwegian Cod Measurements.

Up to 1929 the measurements were made to the nearest centimetre. Since then un-grouped measurements have been obtained by the D'Arcy Thompson millimetre paper-method (slightly modified). The data are treated in cm.-classes throughout, the abscissæ of curves (x) always increasing by whole centimetres. Smoothing is always applied at a certain stage. Before 1925 the smoothing formula used was $(y_{x-1} + y_x + y_{x+1}) : 3$; since 1926 the formula $(y_{x-1} + 2y_x + y_{x+1}) : 4$ has been applied.

In explaining the ordinates or number within any cm.-class (y) of the different graphical representations which have been found useful in considering fluctuations, the following system of symbols is used:

1. Symbols of Quantity.

y = ordinates referred to any year or part of year or single sample,
Y = ordinates referred to a period of years, the first and the last year inscribed below and above the Y,
N = number of fish,
f = number of fishermen fishing from a certain port, during a certain week
φ = number of fishermen fishing from a certain port, during the season.
d = number of fishing days during a certain week,
D = number of fishing days during a season.

P = product of fd,
A = $N : P$,
l = average proportion of catch of spawning cod in northern Norway,
m = average proportion of catch of spawning cod in southern Norway,
s = average proportion of catch of spawning cod in relation to total Norwegian catch of cod,
f = average proportion of Finmark fish (young and mixed ($l + m = 1$, $s + f = 1$).

2. Symbols of Operation (upper indices).

m to denote measurement ordinates,
o to denote ordinates reduced to a sum of 10000.
v to denote ordinates weighted by the catch of a district,
w to denote ordinates weighted by the catch per man and per day (eventually multiplied by a scale coefficient),
q to denote ordinates expressed as percentages in relation to ordinates averaged (over a period of years),
d to denote ordinates from which the corresponding average ordinates (over a period of years) have been subtracted,
qd to denote differences between any corresponding ordinates y^o.

3. Symbols of Season (calendar years) and periods are written

as middle indices, or as the indices applied to the summation and integral symbols respectively, thus:

$$y^{1932},\ y^{1931},\ y^{19nn}\ \overset{1932}{\underset{1913}{Y}},\ \overset{19nn+n}{\underset{19nn}{Y}},$$

4. Symbols of Area (written as lower indices behind the quantity symbol).

L = Lofoten (for measurements) or the whole of North Norway (for seasonally weighted ordinate),
M = District of Møre or the whole of South Norway, similarly as L for N. Norway.
S = combinations of L and M or the whole of the spawning cod fishing area.
F = Finmark spring-cod fishery,
T = the aggregate "great" cod fisheries of Norway,
$\alpha, \beta, \gamma, \delta$, = the several fish measurers, or places where fish are measured,
1,2,3- n = the various supervision districts rendering statistics.

5. Symbols of Epoch (weeks, fortnights) written as *lower* indices before the value symbol.

$a,b,c \ldots f$ = the consecutive fortnight periods of a fishing season,

$1,2,3 \ldots r$ = the consecutive statistical weeks of a fishing season.

Data derived from measurements in the three main fishing areas: Lofoten, Finmark and Møre, are denoted by the indices L, F, and M.

In each of these three main areas 1 to 4 measurers are working so as to cover the area as thoroughly as possible. These measurers are denoted by the indices α, β, γ, δ.

For each measurer the measurements are added for each of the 6 or 7 fourteen day periods of the season denoted by $a, b, c \ldots f$ as lower anterior indices. Thus the following ordinates are obtained:

$$ {}_a y^m_{L\alpha},\ {}_a y^m_{L\beta},\ {}_b y^m_{L\alpha},\ {}_b y^m_{L\beta}, \ldots\ {}_f y^m_{L\delta} $$

$$ {}_a y^m_{M\alpha},\ {}_a y^m_{M\beta}, \ldots\ {}_f y^m_{M\delta} $$

$$ {}_a y^m_{F\alpha},\ {}_a y^m_{F\beta}, \ldots\ {}_f y^m_{F\delta} $$

If necessary the upper index ^{m} is applied to show that these series are *untreated* measurements except by adding together those made at one place within one fortnight. Thus ${}_b \overset{m}{y}{}^{1932}_{F\gamma}$ denotes the aggregate number of fish within any cm.-class measured in 1932 during the 2nd fortnight (b = May 1—15) by the fish-measurer stationed within the third division (γ) of Finmark (F).

In order to present these, it is necessary to smooth the series and to reduce each to a standard total (as the number measured may vary considerably) and for this purpose the number 10,000 has been found convenient, giving maximum ordinates of about 300—500. These new ordinates y^o are arrived at thus:

$$(1)\quad y^o = \frac{y^m}{\Sigma y^m} \cdot 10^4; \quad \text{and} \quad {}_a \overset{o}{y}{}^{1932}_{L\alpha} = \frac{{}_a \overset{m}{y}{}^{1932}_{L\alpha}}{\Sigma\ {}_a \overset{m}{y}{}^{1932}_{L\alpha}} \cdot 10^4$$

and so on.

Series representative of the whole area for the whole season are formed by introducing the total catch (in number of fish) for each division and fortnight; these catches are denoted by N, thus

$$ {}_a N_{L\alpha},\ {}_a N_{L\beta}, \ldots\ {}_f N_{M\gamma},\ {}_f N_{F\gamma}. $$

Applying these quantities as weights we obtain the weighted ordinates y^v:

$$y^v = \frac{y^m}{\Sigma y^m} \cdot N.$$

These weighted series may be added.

We have

$$N_L = {}_aN_{L\alpha} + {}_aN_{L\beta} + \ldots\ldots {}_fN_{L\delta},$$
$$y^v_L = {}_ay^v_{L\alpha} + {}_ay^v_{L\beta} + \ldots\ldots {}_fy^v_{L\delta}$$

and by reducing this series to 10,000 we obtain

$$(2) \qquad y^o_L = \frac{y^v_L}{\Sigma y^v_L} \cdot 10^4$$

and in the same way y^o_M and y^o_F, the number of fish per 10,000 in any cm.-class at Lofoten, Møre or Finmark for a certain year. See Fig. 6 and 9.

In order to compare the three different main areas and different seasons it has been thought necessary not only to consider the catch, but also the expenditure of catching power. As a unit for this the fishing methods of Norway make it natural to choose:

"one man fishing one day", or "a day's work at sea".

Data to this point are supplied by the fishery supervision service as weekly figures, namely the number of fishermen (f) present at the port during the week and the number of utilizable fishing days (d) each week. The product-sum of these figures gives the total fishing power (P) expended in the area during the season.

Thus:

$$P = \Sigma fd = {}_1f_1 \cdot {}_1d_1 + {}_1f_2 \cdot {}_1d_2 + \ldots\ldots + {}_2f_1 \cdot {}_2d_1 + {}_2f_2 \cdot {}_2d_2 + \ldots\ldots + {}_rf_n \cdot {}_rd_n$$

the anterior indices denoting the consecutive weeks of the fishing season, the posterior the various fishing ports.

By means of this P we obtain the average catch per fishing unit, A: $\qquad A = N : P.$

Thus:

$$A_L = N_L : P_L\,;\; A_M = N_M : P_M;\; A_F = N_F : P_F$$

The calculation of P in the way given above applies only to the years after 1923. To obtain the corresponding values for earlier years it was necessary to have recourse to another method owing to lack of weekly data, viz. simply taking the number of fishermen present at the height of the season, φ, multiplied by the number of fishing days, D, of the whole season.

For those years in which both sets of data were available both P and $D\varphi$ could be calculated and the result is that the ratio $D\varphi : P$ is seen to vary at Lofoten between 1.47 and 1.65, the average being 1.563, the standard deviation, 0.062. No great error is therefore committed, when P is used with a factor $^3/_2$ in order to preserve the scale originally adopted for those graphical representations which involve consideration of the catch per unit of fishing.

Having established the magnitudes A_L, A_M and A_F we are able to calculate the number of fish in each cm.-class per unit of fishing, y^w, which is defined thus (having regard to the desired scale):

(3) $y^w_L = y^o_L \cdot A_L : 15$; and similarly y^w_M and y^w_F.

(See Fig. 6, middle right-hand graph.)

These values have been used to form the average ordinates Y for the available number of years (1913—1932), thus

$$(4) \qquad {}^{1932}_{1913}Y^w_L = \frac{1}{20}\left(y^w_{L\,1913} + y^w_{L\,1914} + \ldots + y^w_{L\,1932}\right);$$

so Y^w_M and Y^w_F.

(See Fig. 6, middle right-hand graph.)

These average ordinates Y^w may be converted into the average ordinates:

$$(5) \qquad {}^{1932}_{1913}Y^o_L = \left[{}^{1932}_{1913}Y^w_L : \sum {}^{1932}_{1913}Y^w_L\right] \cdot 10^4$$

and similarly ${}^{1932}_{1913}Y^o_F$ and ${}^{1932}_{1913}Y^o_M$.

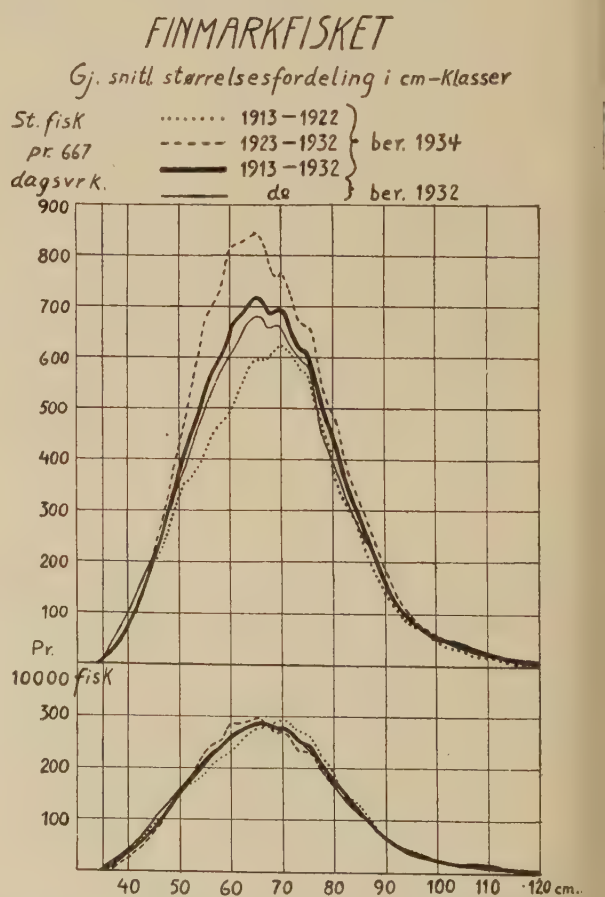


Fig. 4. Average distribution of sizes of Finmark cod. Areas of upper curves corresponding to average catch per man per day, areas of lower curves equal to 10,000 fish.

A representation of Y_F^o and Y_F^w for the entire 20-year period 1913—1932 as well as for the two decades separately is given in Fig. 4. (Also Fig. 6, upper right-hand graph.)

Applying the average ordinates (4) and (5), we may form two interesting series which are found to be the most useful when considering fluctuations, namely (6) and (7):

(6) $y^q = \frac{y^w}{Y^w} \cdot 10^2 - 10^2$; thus y_L^q, y_M^q and y_F^q.

(See Fig. 6, lower right-hand graph.), i. e. percentage excess or deficit number of fish in any centimetre-class at Lofoten, Møre or Finmark in any year. Further:

(7) $y^d = y^o - Y^o$; thus y_L^d, y_M^d and y_F^d

(See Fig. 12, middle row (F)), i. e. excess or deficit number of fish per 10,000 in any cm.-class at Lofoten, Møre or Finmark in any year.

Finally it has been found interesting to show the change taking place in the stock from one year to another in point of size and relative quantity (A). This is most simply achieved by forming

(8) $y^{qd}_{L\ 19nn} = y^{q}_{L\ 19nn} - y^{q}_{L\ 19nn-1}$

Thus y_L^{qd}, y_M^{qd} and y_F^{qd}, i. e.: change in percentage number of fish per unit catching power from one year to another at Lofoten, Møre and Finmark.

Combination of Data from the three Areas.

As the fish caught at Lofoten and Møre, in fact all along the coast from West Finmark to Bergen, during spring are migrating spawners and the distribution of sizes may in some years be more or less dissimilar, it has been felt desirable to get a view of the army of skrei or spawners by combining in some way the values y_L and y_M, i. e. by adding them after weighting them appropriately.

Several ways of doing this might be conceived.

A little consideration soon shows that the magnitude A_L, A_M and A_F cannot be used for this purpose, as no account is thereby taken of the relative importance of the three areas, since A is a relative magnitude which may be very small for a big area and very large for a quite unimportant one. The same is true in a lesser degree of the average of A over a series of years. The use of such a figure pre-supposes that the districts to be combined are of nearly the same importance; it is, on the whole, impossible to escape from the necessity of assessing the relative importance of the districts in some way. To define the importance of an area one might consider such magnitudes as the length of coastline or area of fishing banks — very impalpable objects to define — or one might point to the average total fishing effort or to the average absolute output. The last-named seems preferable from many points of view. It seems quite reasonable in itself and is also the easiest to ascertain for a lengthy period. See table 5.

Based on these considerations we have decided on the following methods of combining the ordinates y^w relating to the northern and southern skrei area, using the index S for the combined skrei stock:

(a) $y_S^w = y_L^w \frac{\Sigma N_L}{\Sigma(N_L + N_M)} + y_M^w \frac{\Sigma N_M}{\Sigma(N_L + N_M)}$

and further, the index T denoting the whole of the cod population as affecting all Norwegian seasonal cod fisheries:

(b) $y_T^w = y_S^w \frac{\Sigma N_S}{\Sigma(N_S + N_F)} + y_F^w \frac{\Sigma N_F}{\Sigma(N_S + N_F)}$

Table 5.

Average output (in thousands of fish) of the Norwegian Cod Fisheries during Various Periods.

District	1902—12	1914—28	1913—32	1902—32
Skrei:				
1) Finmark	2,090	1,905	2,470	2,339
2) Tromsfylket	2,580	860	1,002	1,562
3) Nordland	22,100	21,235	23,933	22,950
4) Trøndelagen	4,220	3,070	3,124	3,510
5) Møre	7,000	7,413	6,771	6,852
6) S. of C. Stat	1,036	3,294	2,638	2,070
A) Northern Norway (1+2+3)	26,770	24,000	27,405	26,851
B) Southern — (4+5+6)	12,256	13,777	12,533	12,432
C) Skrei, total (A+B)	39,026	37,777	39,938	39,283
Loddetorsk:				
7) Finmark	23,800	22,870	22,107	22,714
D) Cod, total (C+7)	61,826	60,647	62,045	61,997
Ratios:				
A/C = l	0.685	0.636	0.686	0.683
C/D = s	0.622	0.623	0.644	0.634

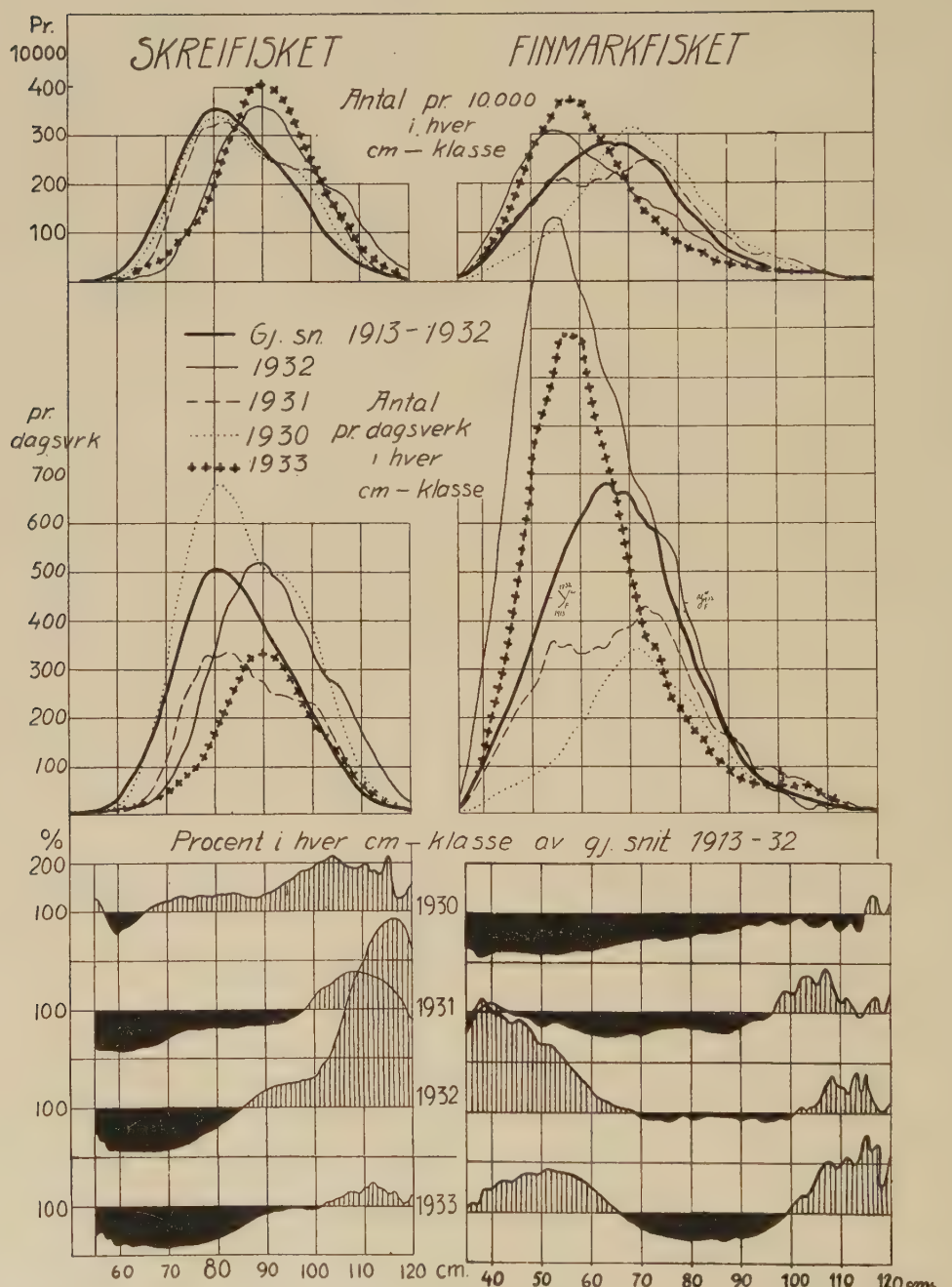


Fig. 6. Review of Norw. cod measurements 1930—33, separately for spawning (winter) fishery ("Skreifisket") and for the Finmark spring-fishing. Upper curves of equal area (10,000 fish), middle curves of area corresp. to catch per man per day, — each square $1^1/_2$ fish per man per day.

We will express the unwieldy fractions in the equation (a) by l and m, those in the equation (b) by s and f. These equations will then read:

(9) $$y_S^w = l y_L^w + m y_M^w$$

Number of skrei of any cm.-class caught any year per unit effort (multiplied by $^2/_3 \cdot 1000$). (See Fig. 6, middle left graphs.)

(10) $$y_T^w = s y_S^w + f y_F^w = s l y_L^w + s m y_M^w + f y_F^w$$

Evidently:

$$l + m = 1;\ s + f = 1;\ sl + sm + f = 1.$$

We get also:

(11) (12) $$y_S^o = \frac{y_S^w}{\Sigma y_S^w} \cdot 10^4 \text{ and } y_T^o = \frac{y_T^w}{\Sigma y_T^w} \cdot 10^4$$

(See Fig. 6, upper left graph.)
Further:

(13) $$\overset{1932}{\underset{1913}{Y_S^w}} = l \overset{1932}{\underset{1913}{Y_L^w}} + m \overset{1932}{\underset{1913}{Y_M^w}} \text{ and}$$

(14) $$\overset{1932}{\underset{1913}{Y_T^w}} = s \overset{1932}{\underset{1913}{Y_S^w}} + f \overset{1932}{\underset{1913}{Y_F^W}}$$

and corresponding to (11 and 12):

(15) (16) $$\overset{1932}{\underset{1913}{Y_S^o}} \text{ and } \overset{1932}{\underset{1913}{Y_T^o}}$$

No. (13) and (15) are represented in Fig. 6, middle and upper left graph.

These are the average numbers of skrei for the years 1913 to 1932, i. e., total cod in any cm.-class per unit of fishing effort respectively (multiplied by $^2/_3 \cdot 1000$).

We are now able to get the values (17, 18 and 19), i. e. (17) percentage excess or deficit within any cm.-class in any year (relative to the average for 1913 to 1932) for the Norwegian skrei (spawning cod) fisheries, and (18) the same, relative to the aggregate cod fisheries, and finally (19) the differences between the corresponding ordinates of the last named character for two consecutive seasons, (see Fig. 6, lower graph).

(17) $$y_S^q = \frac{y_S^w}{Y_S^w} \cdot 100 - 100$$

(18) and $$y_T^q = \frac{y_T^w}{Y_T^w} 100 - 100$$

(Fig. 13, left row)

(19) $$y_T^{qd}{}_{19nn} = y_T^q{}_{19nn} - y_T^q{}_{(19nn-1)}$$

(see Fig. 13, right row).

The idea of trying to get an insight into the state of the stock of cod by means of investigating the catches of our fishermen originated in 1913 as a consequence of the demonstration by Dr. Johan Hjort regarding stock fluctuations as a prime factor in output fluctuations.

During the first years, (from 1913 to 1919) most attention was paid to scale readings, and the number of fish handled was therefore restricted to a few thousands. As it was gradually realized that scale readings were less trustworthy than at first supposed and that they were more or less impossible in far too great a percentage to allow of a really satisfactory division of the catches into year-classes, more attention was given to the possibilities of an extended measurement work, and since 1920 the number of fish handled has been increasing up to the present level of about 150,000 fish (in 1933: 144,616).

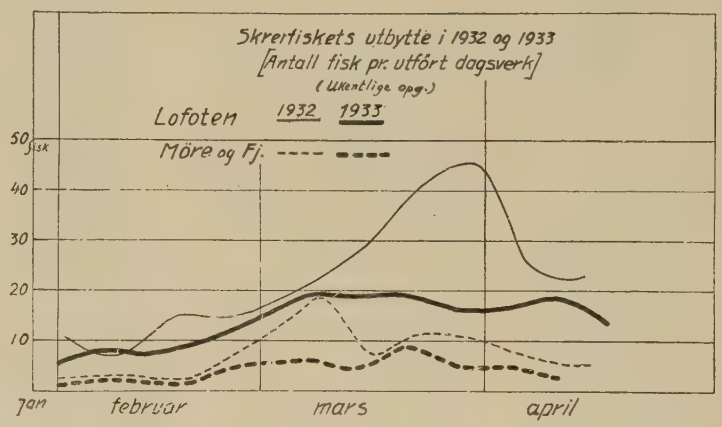
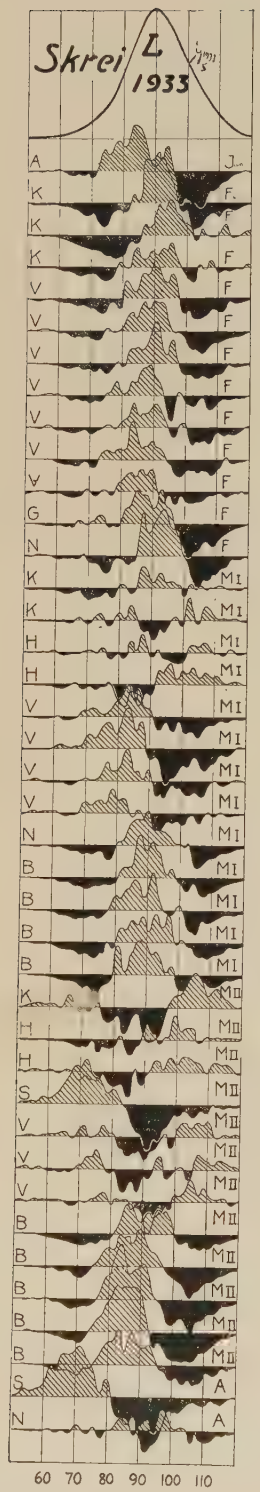


Fig. 5. Weekly output of winter cod fishing at Lofoten and at Møre per man per day.

The possibility of measuring large numbers of big fish such as cod was greatly improved in 1929 by the introduction of the D'Arcy Thompson "blind-measuring" method which furthermore greatly enhances the statistical value of the measurements, as this method does away with nearly the whole of the "personal" factor.

The idea of weighting measurement series by means of the statistical data furnished by the fishery supervision service was introduced in 1921 and the treatment of the material on the lines described here in 1925.

The necessity of using the data per centimetre instead of 5 cm.-classes was realized as early as in 1916, but could not give any valuable results until combined with the method of treating measurement series as differences or percentages of averages; and useful averages could not, of course, be satisfactorily formed in the earlier years of the work, when too few observation years were available, and when those available had yielded only scant material.



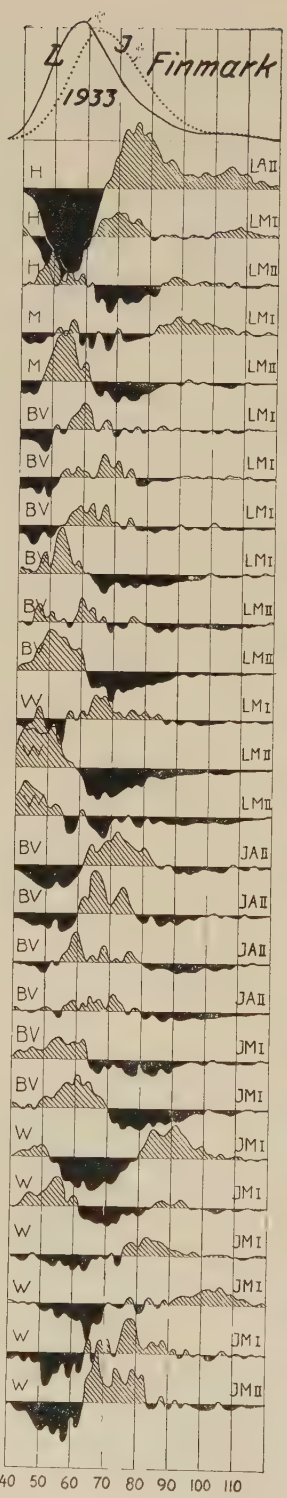
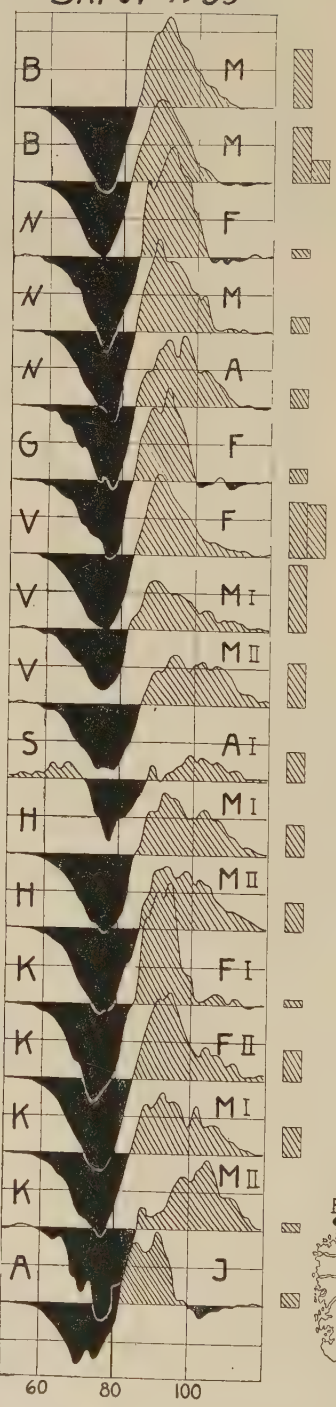


Fig. 7. All 1933 measurements as series of 1—3000 fish, smoothed and reduced to 10,000, expressed as differences from the year's average distribution shown on top of each row. L = line, J = hand-line. Letters to the left of curves denote the place of capture (see map in Fig. 8), to the right the month (I = first, II = second half), for Finmark, also gear, L or J.



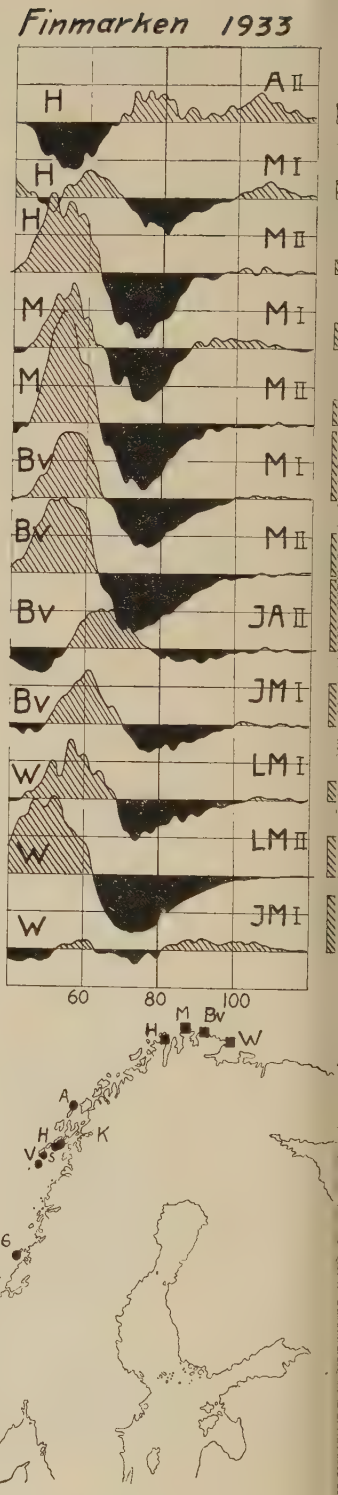


Fig. 8. All 1933 measurements shown as fourteen-day series. Differences from average distribution 1913—1932. Lettering as in Fig. 7. Rectangles on side of graphs proportionate to No. of fish measured.

III. The Norwegian Cod Fisheries in 1933.

A brief report is given below of cod-measurements of commercial catches during the extensive seasonal fisheries as compared with the haphazard data collected by the fishery supervision service in respect of the quantities landed, the number of fishermen in each supervision district (frequently comprising but a single port or a few ports near to each other) and the number of actual fishing days per week.

Points at the coast at which cod were measured are marked on the chart, Fig. 8. A total of 142,000 fish were measured, 62,000 of them at Finmark in April-June, and 80,000 skrei (spawning cod) in January-April (at the two southern groups of points plotted on the chart). The number of cod measured since 1927 inclusive amounts (in thousands) to: 73, 76, 59, 104, 64, 184, 142.

The gear used in Finmark are almost exclusively the hook, the hand-line and particularly the long-line. During the skrei-fishery gill-nets are also used. None of the gears may be characterized as selective. The mesh-width of the nets are adapted fairly well in accordance with the predominating size. The major part of the material measured has been hook-caught fish. As previously mentioned, since 1930 (inclusive) more measurements are made by the "blind" or "awl"-method.

The yield of the fishery was rather poor in 1933 as compared with that of the previous year, in Finmark as well as in the skrei-district. It thus seems that certain factors have influenced the migrations along the entire coast.

As regards Finmark it may be stated (from observations made on the cruise of the "Johan Hjort" in June) that heavy masses of "warm" water ($> 3°$ C.) appeared along the coast and experience has proved that the best fishery at Finmark occurs at a temperature of about 2° C. At Lofoten the situation was influenced by the fact that the intermediate layer, between the cold coastal water and the Atlantic water below, was so thin that the fishermen had difficulties in locating the fish. They rarely kept to the bottom, experience proving that they are strongly tied to the intermediate layer with temperatures between 4.5 and 6° C. The experiences of the 1933 season have been utilized this year to a considerable extent by the gill-net fishermen, who in most cases take good care to keep the nets at the correct depth by means of extra surface floats and properly adjusted carrier-lines. This has proved very effective and the yield of this gear has been very satisfactory this year, while that of the line fishery shows only poor catches. This is also due to another cause, namely the fact that the liver of the fish this year is very large and fat and the fish, therefore, are not hungry for bait.

The progress of last year's skrei-fishery is illustrated by Fig. 5 and shows considerable difference from that of 1932, inasmuch as the yield per day's fishery kept very even and low during the whole season. Off the southern coast it was similar to that of a series of years as far back as 1915, with a single exception (1926). During this period several good seasons have occurred at the northern coast and the cause of this must, therefore, be due solely to peculiarities only of the oceanic circulation which during the later years has proved very unsatisfactory for the migration southwards of the spawning cod.

Fig. 6 attempts to give a comprehensive statement regarding the quality of both Norwegian cod fisheries. The size distribution among the spawning cod does not differ from that among the 1932 cod, except for the fact that the very large specimens are less abundantly represented. The concentration seems, however, to have been smaller, although the conditions mentioned above regarding the water layers may account for this fact. According to the diagrams of Johannes Lundbeck (see this volume) no cod larger than 100 cm. have been caught off the Norwegian coast in any number worth mentioning, but this does not apply to the catches on the "Skolpen" bank where the large cod caught amounted to about 20 % against almost 30 %, in 1932, about the same

Table 6.

Yearly average weight of the cod in the main fishing areas in Norway and output per man per day.

Season	Weight per fish (gutted and headed)			No. of fish per man per day			Kg. per man per day		
	Møre	Lofoten	Finmark	Møre	Lofoten	Finmark	Møre	Lofoten	Finmark
1926	3.40	3.40	2.28	30.8	30.3	63.0	105	103	150
1927	3.37	3.37	2.27	13.0	42.8	31.0	44	145	71
1928	3.14	3.56	2.21	10.8	31.2	19.5	34	111	29
1929	3.17	3.41	2.27	10.4	37.2	32.9	33	127	75
1930	3.53	3.72	2.49	17.8	36.5	17.7	63	135	44
1931	3.59	3.94	2.23	9.2	17.8	25.0	33	70	56
1932	3.77	4.43	1.65	10.4	27.4	51.3	39	122	84
1933	4.07	4.25	1.67	5.1	15.5	39.5	21	66	66

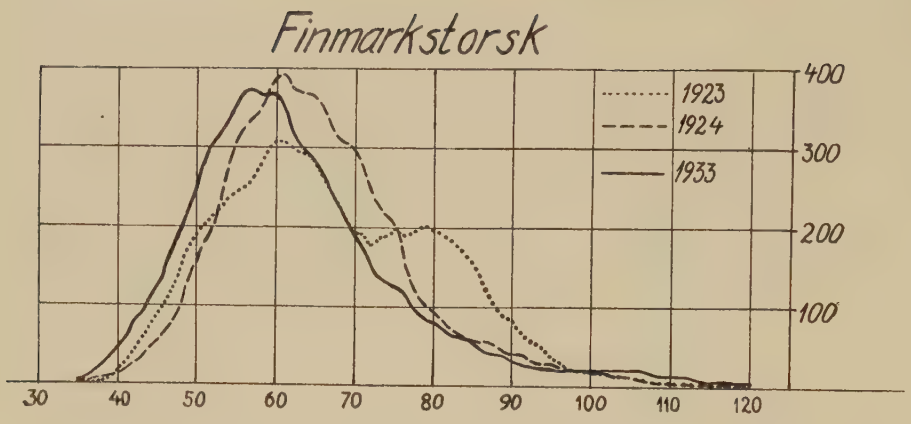


Fig. 9. Length distribution of 10,000 Finmark fish in 1923, 1924 and 1933.

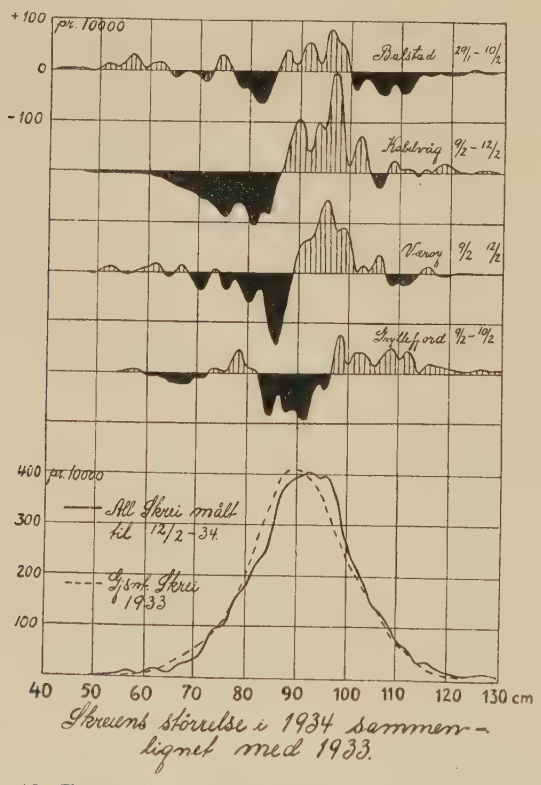


Fig. 10. Four series of measurements in February 1934, shown as differences from 1933 distribution. Below sum of the 4 series compared with total curve for 1933.

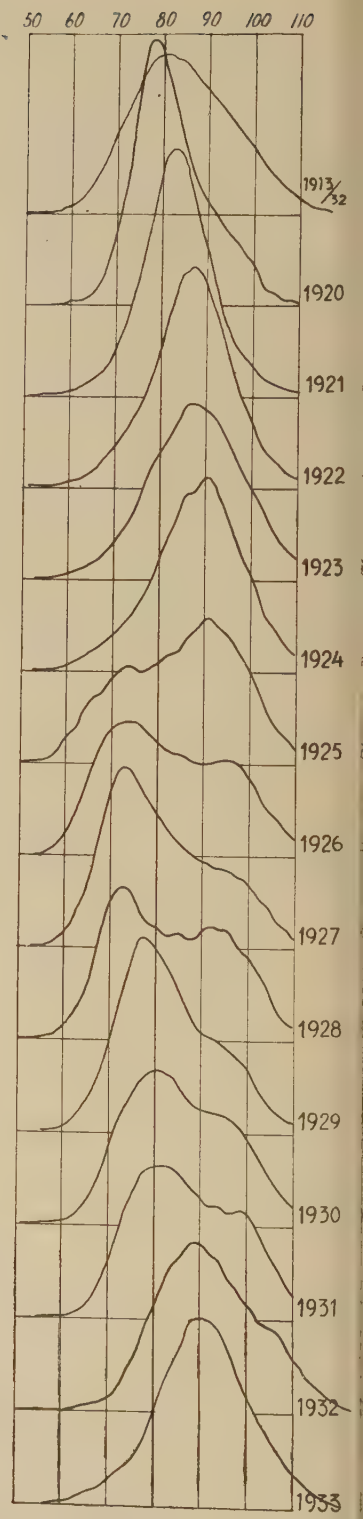


Fig. 11. Length distribution of (10,000) spawning cod for each year 1920—33 and average 1913—32. Cm.-scale on top

as during the Norwegian winter fisheries. These large fish originate from the rich 1919 year-classes, but there were also many from the 1918 and 1920 hatches.

The character of the Finmark fishery is illustrated on the right-hand side of Fig. 6. As already mentioned, the yield was considerably less than the previous year, but the sizes had altered less than might have been expected if no additional stock was present from a new year-class in 1933 also. During May, so many small fish of the 1929 year-class arrived that the stock of small fish, now dominating the Finmark fishery, consists mainly of three consecutive year-classes, 1927 to 1929. This favourable constellation has influenced the fishery as early as this year, a very promising fishery being in full swing in West Finmark. Except for local variations, LUNDBECK's presentation shows that in other parts of the Barents Sea also the same development in the size of young fish has taken place, or rather that the most conspicuous maximum, at about 60 cm., did not move to the right from 1932 to 1933.

Fig. 7 shows the details of the measurement material, although not in single series of measurements, but in groups of 1—3000 individuals measured at the same place within a few days. Each of these "secondary" series is reduced to tens of thousands (10,000) from which the average series for the year has been deducted. It will be seen that the stock of skrei has been comparatively homogeneous. The only essential exceptions are the measurements at Sörvågen (S) near the southern point of Lofoten during the last fortnight of March and during April. According to the latest investigations by ROLLEFSEN (this volume) these samples have probably contained a certain amount of coastal cod having no special relation to the Barents Sea cod, which, of course, is the most important object of Norwegian cod fisheries.

As regards the Finmark material, this has been divided by gears, viz. line (L) and hand-line (J). The samples show considerable variations indicating that the fish arrive at the coast in separate shoals, each particular one with a dominating year-class.

Fig. 8 shows the material compiled by fourteen-day series for each measuring station and represented by differences from the mean distribution for the period 1913—32. The illustration clearly shows the drastic contrast between the skrei-stock on the one hand — an overaged remnant-stock — and the Finmark fish, on the other hand, with a heavy accretion of new year-classes.

When will this new recruitment predominate in the main fishery, the winter-season? It should be possible to obtain some idea of this by investigations of the observations of earlier years in order to find a situation similar to the present one, and it is thus obvious (from a study of Fig. 12) that the years 1923 or 1924 in particular appear to be parallel to the present situation. Comparison of the y^o-curves for the said years with those of last year's Finmark fish proves that 1923 is the year most resembling 1933. Prior to the commencement of the winter-fishery it could, therefore, be said that most probably the year 1934 will not show any additional stock of young fish accruing to the spawning shoals (see SUND: Torskebestanden (stock of cod) in the publications of the Fishery Directorate, Vol. IV, No. 7, Bergen, 1934). Measurements made to date (April 10, 1934) have proved this forecast to be correct. See Fig. 10 showing some measurements during February at Lofoten. Later measurements show no essentially different character. Next year, however, young fish may be expected in the catches of the winter-fishery.

IV. The Fluctuations of the Arcto-Norwegian Cod Stock from 1913 to 1933.

Equal-area curves of the size of the winter-cod during the last 14 years, Fig. 11, show the heavy variations to which this has been subject. This period is specially depicted, because the data from this period are the best. At the top of the figure mean-curves for all the years 1913—1932 are shown. It will be noted that no single year corresponds with the mean curve. Although the average size in some years almost equals those of 1921 and 1923, the shape of the curve, on the other hand, is essentially different; no "mean year" has occurred and most probably will never occur.

Fig. 12 illustrates all measurements made from 1913 to 1933; each curve is constructed from the distribution of 10,000 fish less the respective averages for the 20-year-period, 1913—1932. The three series of curves all distinctly show these earlier variations of stocks, the first of which commenced with the winter-fishery (the skrei fishery) of the year prior to the commencement of the measurements (1912), in the Finmark-fishery in 1909, the second rise commenced in Finmark in 1916, in the skrei in 1919; the third in Finmark in 1921, in the skrei in 1925. The fourth rise which is not as yet apparent among the skrei, commenced in Finmark in 1931 and is expected to show results during the skrei-fishery of 1935. This is clearly noticeable from the middle and the right-hand range of curves (the Finmark fishery and total stock). It will also be seen from the middle range of curves that between the second and the third decided rise-curves an attempted renewal of the Finmark stock in 1920—22 (1915 year-class) was noticed, not strong enough, however, to leave any pronounced trace.

The left-hand range of curves shows for the last 4 years (1934 may also be included) an extraordinary fact, namely, that the spawning shoals consist almost entirely of very large (and old) fish only. According to ROLLEFSEN (this volume), it is evident that a very large number of these old fish, some of

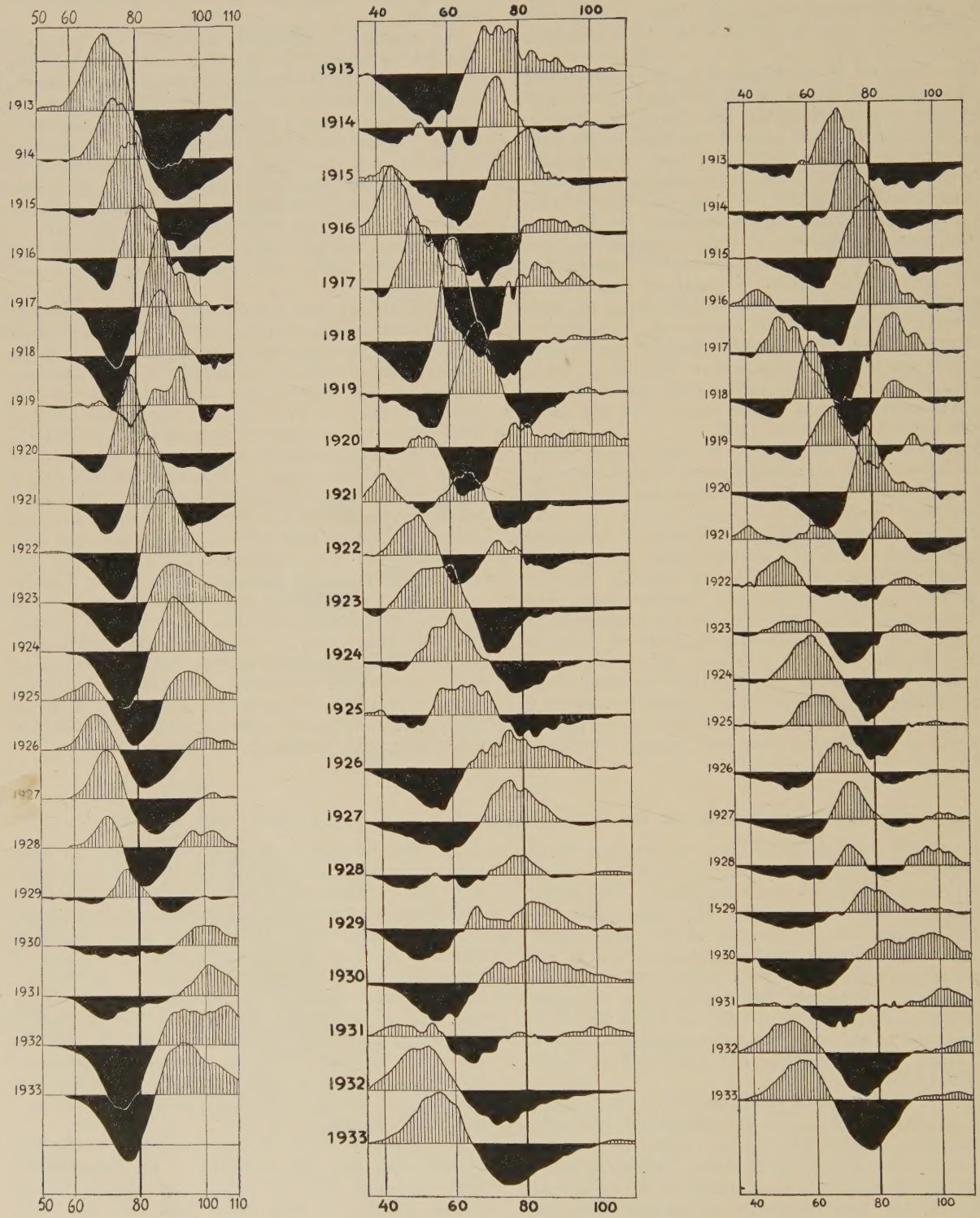


Fig. 12. Length distribution of winter (spawning) cod (left row), spring (Finmark) cod (middle row) and of both combined (right row), all reduced to 10,000 and shown as differences from average for 1913—32.

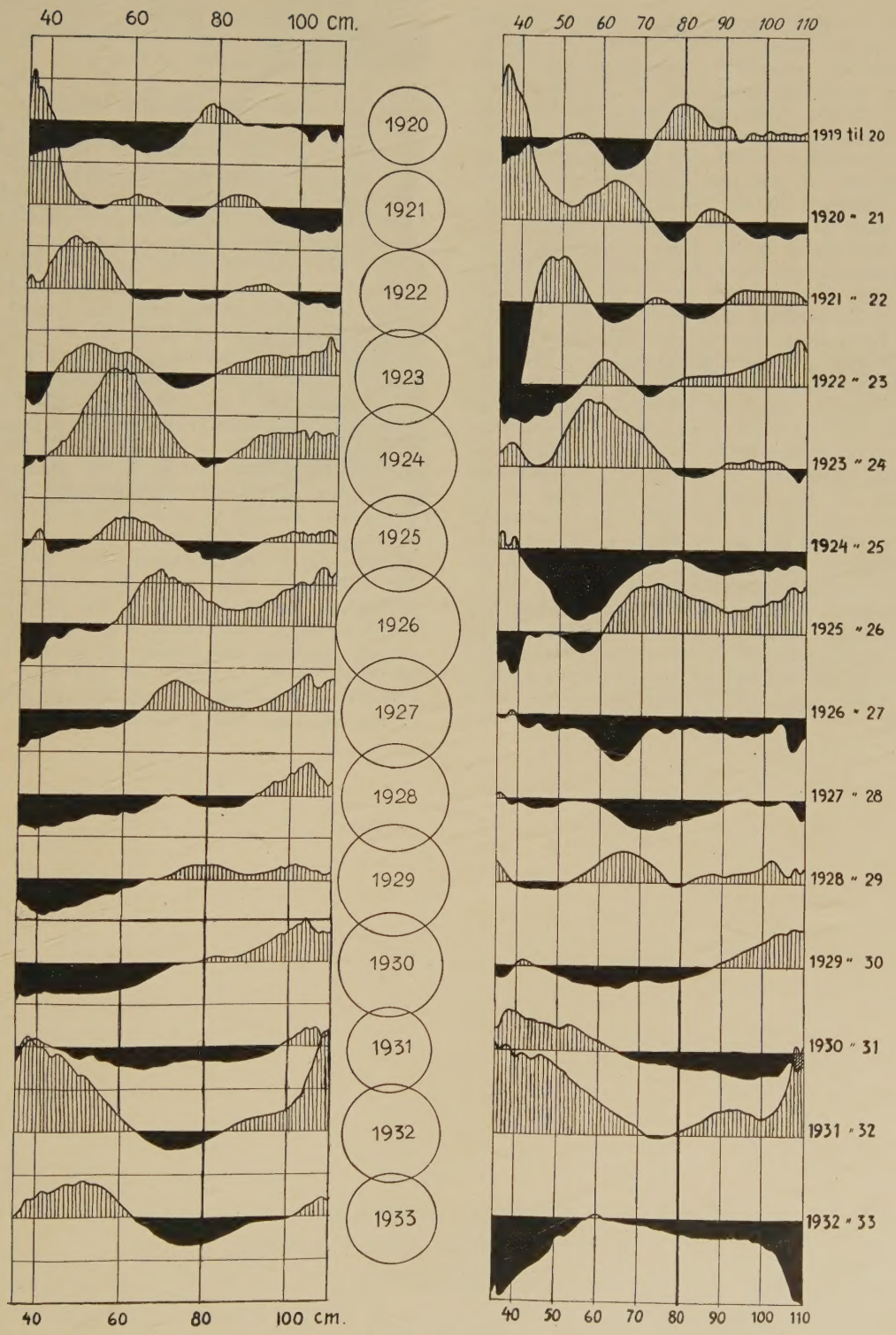


Fig. 13. Left: Percentage excess (shaded) or deficit (black) in each cm.-class per man per day for entire cod fishery combined. Space between horizontals equal to 100 %.
Right: Change from year to year. The frequencies used for the left row graphs deducted from the corresponding ones of the succeeding year.
Areas of circles to total yearly catch in tons.

which are even up to 16 years old, have never spawned before. It seems thus that the Barents Sea during recent years has concealed a reserve of fish which under the conditions prevailing in previous years would as younger individuals have benefited the Norwegian coastal fishery. Is it possible that there is any connection between this late appearance of these large-cod as spawners and the considerable stock of large-cod in the "Kanin" area? (Lundbeck). It may be assumed that the exceedingly rich stock of food-stuffs in the form of bottom fauna which the Russian scientists (Zenkewitch, Brotzky, and Idelson: Materials for the study of the Productivity of the SeaBottom in the White Sea, Barents Sea and Kara Seas, Journal du Conseil, Vol. III, No. 3, 1926) have proved to exist in this very "Kanin" area and north thereof, has always existed, and we are therefore forced to assume that latter years have been characterized by a peculiar circulation in the Barents Sea. Norwegian researches of the Finmark coast have proved that these last five years in particular are conspicuous by the accumulation of rather warm water masses off this coast and that the shoals which have come within the reach of the fishermen have been located on the borders of these water masses, viz. where the bottom temperature has been 2—2½°. As this border is, as a rule, located rather far from the coast, the fishery has consequently been exceedingly poor and would no doubt have been a total failure if the more primitive methods used in previous years, such as open boats without motor etc., had been employed.

The last figure (13) purports, besides showing the variation of sizes, to give an impression also of the variations in the density of the stock, as far as this can be judged on the basis of the average daily yield per man. The left-hand range of curves is constructed as a percentage excess (or deficit) in proportion to the average of the whole period 1913—32, this offering the advantage that the variations of the extreme size-classes, which must necessarily always be small, may also appear and show the tendency of the development. The result is that the small series of peaks which in Fig. 12, middle row, first appears in 1920 at about 50 cm., is hardly noticeable in the left-hand row of Fig. 13.

The second range of curves on Fig. 13, which is obtained by a successive subtraction of one year's range of curves from that of the following one, does not perhaps give any fresh information. It shows nevertheless that the yield of fish has not only been subject to variations of the stock itself, but also to a great extent to the fact that the quantities of fish in question have migrated into the very district where they are apt to come within the reach of the Norwegian coastal fishermen.

Consequently investigations into the catches of the Norwegian fishermen can hardly give any exhaustive information as to the quantity of the Arcto-Norwegian cod stock, even though the information regarding the quality of the stock seems to be rather good, to judge by the good agreement with the results obtained by the German investigations on the fish from the entire Barents Sea.